Operating and Monitoring Manual

Interim Guidelines

May, 1991

British Columbia
Mine Waste
Rock Pile
Research
Committee

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OPERATION AND MONITORING OF MINE DUMPS

INTERIM GUIDELINES

Prepared for the:

British Columbia Mine Dump Committee with funding provided from the Provincial Sustainable Environment Fund

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FOREWORD

Mine waste rock and overburden dumps are massive structures, for example, mountain top coal mines in British Columbia are constructing the largest man-made structures on the face of the earth. These immense waste dumps are often up to 400 meters high, designed to contain in excess of 1 billion cubic meters of material and often form mid-valley fills or rock drains. Instability of the structures has caused increased concern by the mine operators and the government regulators because of impacts on the environment and risk to the safety of personnel, equipment and infrastructure.

In mid 1990 representatives of industry, CANMET and the ministries of Environment and Energy, Mines and Petroleum Resources formed a committee to foster research work and ensure a common understanding of these waste dumps.

These Interim Guidelines form one of a series of studies undertaken by the committee. Prominent geotechnical consultants and industry representatives have reviewed the guide and many of their suggestions have been incorporated.

I would like to stress that this document is purely for guidance and to assist in developing a standardization of approach in pre-design investigation and also in design analysis.

Over the course of the next year it is the intent of the committee to evaluate and verify the innovative classification system developed by the authors and also to encourage constructive comment from industry, regulatory personnel and consultants. In early 1990 the committee is proposing to sponsor a series of workshops to introduce all of the studies to key industry personnel and capture the practical experience of a year of using the guidelines so that a planned rewrite can incorporate that experience.

The guidelines are being widely distributed by the Ministry of Energy, Mines and Petroleum Resources in the hopes that all concerned with mine dumps will find them useful in establishing dumps that are stable, safe and economically feasible, as well as to solicit your comments.

R.W. McGinn, P.Eng.
Chairman, Waste Dump Research Committee May 21, 1991

May 21, 1991

SUMMARY

This document, produced for the Province of British Columbia Ministry of Energy, Mines and Petroleum Resources (MEMPR), presents guidelines for operation of mine dumps. The intent of the guidelines is to establish, where possible, a basis of uniformity so that regulations and operating criteria for mine dumps are applied consistently throughout the province, thereby diminishing the frequency of mine dump failures. The guidelines are supplementary to the provisions of the Mines Act and the Health, Safety and Reclamation Code for mines in British Columbia. Information on mine dump operations was assembled through a literature search, a questionnaire filled out by operating mines, and through site visits and/or interviews with District Inspectors and mine operators. Comments on a draft copy of the guidelines were received from reviewers, including operators, regulators and consultants.

The guidelines present operating and safety procedures based primarily on a literature review, discussion, judgement and existing dump operations manuals provided by the mine operators in British Columbia. General areas of responsibility are defined. Recommendations are made with respect to dump loading rates and allowable crest movement rates, but safe limits on such aspects should be developed for each site. It is recommended that every British Columbia mine which operates mine dumps use these guidelines or develop site-specific guidelines based on this document.

General requirements for dump monitoring are presented. Monitoring may include crest movements, slope movements, toe movements, internal deformations, dump saturation levels and foundation pore pressures. The various types of monitoring equipment are described. It is stressed that visual observation remains the most common and is often the most useful method of monitoring. Procedures are presented for assessing, reporting and responding to monitoring results.

The Mine Dump Rating Scheme (MEMPR, 1991) is adopted for rating of mine dump operations. The mine dump ratings are employed to define a table of guidelines for monitoring, inspection and reporting methods and frequencies. A standardized form is presented for periodic inspection of mine dumps.

Dump failures, when they do occur, must be well documented and analyzed to provide improved understanding which may prevent future occurrences. A detailed mine dump failure reporting format is suggested. Failures are also to be reported to MEMPR on the existing form "Advice of Geotechnical Incidents or Unusual Occurrences."

Mine dump planning and operation must incorporate reclamation requirements. To minimize material volumes for resloping, it is desirable, but not always practical, to develop dumps in lifts with intermediate berms. Observation, monitoring and maintenance should be continued on reclaimed dumps to ensure that they will remain stable over the long term.

May 21, 1991

ACKNOWLEDGEMENTS

The authors of these guidelines acknowledge the cooperation of the Ministry of Energy, Mines and Petroleum Resources and the staff of the mines visited (Endako, Highland Valley Copper, Byron Creek, Fording, Balmer and Line Creek) and telephoned in compiling information for this report. We would also like to acknowledge the generosity of Mr. Mark Hawley of Piteau Associates (MEMPR, 1991) in allowing Klohn Leonoff to share in the development and the results of the industry questionnaire. The mine dump classification system developed by Piteau has also been incorporated in these guidelines.

The valuable input of the reviewers listed below is also greatly appreciated. Without their valuable and insightful comments, it would have been impossible to produce this report.

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E. Bonham	British Columbia Environment
C. Brawner	C.O. Brawner Engineering Ltd.
S. Broughton	University of British Columbia
D. Cavers	Hardy BBT
D. Kennedy	Fording Coal
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G. Morgan	Consulting Engineer
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G. Poling	Mining Association of British Columbia
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May 21, 1991

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APPENDIX I - SUPPLEMENTARY INFORMATION

1. INTRODUCTION

Mine dumps associated with British Columbia's mining operations are some of the world's largest man-made structures. These structures are permitted under the Mines Act, which has as its overall mandate the safety and health of the workers at mines, public safety, and the protection and reclamation of the land and watercourses affected by mining activity. The operational procedures for mine dump construction are approved on a site-by-site basis by the appropriate District Inspector and Resident Engineers located in various field offices of the Ministry of Energy, Mines and Petroleum Resources (MEMPR) throughout the province. Constraints on dumping, dump monitoring, dump shutdown due to movement rates, record keeping, loading rates and various other parameters are all within the jurisdiction of the various District Inspectors. This has resulted in inconsistencies in requirements and possibly failures across the province. Notwithstanding local tailor-made procedures, some of these dumps have failed, creating a concern and prompting a desire for some standards.

In addition to this operational guidelines study, the MEMPR commissioned another study to produce guidelines for mine dump design (MEMPR, 1991). More recently, Energy Mines and Resources Canada, Canada Centre for Mineral Technology (CANMET), has commissioned two additional related studies concerning mine dump monitoring technology (CANMET, 1991) and mine dump failure runout analysis (CANMET, 1992).

2. OBJECTIVE

The guidelines presented in this document are primarily intended to reduce the frequency of mine dump failures through the introduction of a uniform set of procedures. Although some mention is made of environmental impact and acid rock drainage, this report is not meant to provide environmental guidelines, nor does it deal with the specific problems of acid mine drainage. These topics are outside the scope of these guidelines.

Several British Columbia mines, particularly coal mines, have experienced large mine dump failures in recent years. Most of these failures have occurred where extremely high dumps, built at the angle of repose, rest on moderately to steeply sloping foundations. However, significant failures have not been restricted to steep mountainside environments. The large quantities involved in these failures have, in some instances, led to large runout distances, concern for human safety and significant environmental impacts. Fortunately, very few injuries or equipment losses have occurred in recent years.

While some failures have involved marginally stable situations and could be attributed to inadequate design, it is apparent upon reviewing the history of British Columbia's mine dump failures that operating procedures also contribute to failures. Such practices as excessively high dumping rates, inclusion of snow in dumps and inappropriate placement of poor quality material and their impact on stability are discussed later in this report.

Under current MEMPR practice, operating guidelines for mine dumps are approved and checked by individual District Inspectors rather than by one central authority. These guidelines will enhance procedural uniformity throughout the province. Through an intensive review of current operating practices, the most appropriate operating measures have been selected to form a uniform set of guidelines. The guidelines are intended to have sufficient flexibility to suit the special and unique needs of the many

different types of mining operation but are not intended to be rigid rules. Safety concerns relating to all facets of dump operation (not limited to dump failures) are also discussed.

Sections 1 through 5 of this report give background information relevant to the study. Sections 6 through 11 give guidelines for mine dump operation and relevant discussion. These sections each include a subsection summarizing the main points and resultant guidelines which precedes the main text.

3. MINES ACT AND HEALTH, SAFETY AND RECLAMATION CODE

All aspects of mining operations in British Columbia are regulated under the Mines Act and the supporting Health, Safety and Reclamation Code for Mines in British Columbia (hereafter referred to as the Code). The purpose of the Code is to:

1. Protect employees and all other persons from undue risks to their health and safety arising out of or in connection with activities at mines.

2. Safeguard the public from risks arising out of or in connection with activities at mines.

3. Protect and reclaim the land and watercourses affected by mining.

4. Monitor the extraction of mineral and coal resources and ensure maximum extraction with a minimum of environmental disturbance, taking into account sound engineering practice and prevailing economic conditions.

Under the Code, the following sections relate either directly or by reference to mine rock dump operations.

Open Pit: Design and Operating Procedures

6.1.1	Notice of Intention to Commence Work
6.1.6	Notice of Intention to Stop Work
6.3.1-6.3.3	Examination of Workings
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9.1.2	Waste Emplacements
9.1.5	Major Dumps
9.2.1-9.2.4	Approvals
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10.1 Mine Plan and Reclamation Program Information
10.2 Notice of Filing
10.3 Referral to Other Agencies
10.4 Permit
10.5 Mine Closure
10.6 Reclamation Standards

4. DATA COLLECTION

4.1 Literature Review

A comprehensive literature review was carried out to assemble information concerning the operation of mine dumps. A large volume of information was amassed in the form of technical publications, consultants' reports and in-house procedural documents from the mines. The most relevant of the published documents are tabulated and annotated in Table 1. A more extensive list of references is given in the References section following the report.

4.2 Survey of British Columbia Mines

A questionnaire was developed to collect all relevant data for this study, as well as for the "Investigation and Design of Mine Dumps - Interim Guidelines" (MEMPR, 1991) being carried out concurrently. The questionnaire was mailed to all operating mines in British Columbia. The collected responses were compiled as an appendix to the Design report (MEMPR 1991). All mine dump operation manuals currently in use at the mines were also collected.

Visits were made to MEMPR offices in Prince George, Kamloops and Fernie, as well as to several mines (see Acknowledgements). The purpose of these visits was to collect information regarding the current status of the mines' dump operational procedures and to review reports of dump failures.

Telephone contact was made with many of the mines to fill in gaps in the data collected through the questionnaire. Site personnel were very helpful, both in filling out the questionnaire and in discussing details when contacted by telephone. Their general willingness to provide information and insight was invaluable in compiling this document.

TABLE 1 - PRINCIPAL REFERENCES

PAPER	APPLICATION AREAS						
	GENERAL	DRAINAGE	SAFETY	MATERIAL PROPERTIES	MONITORIN	RECLAMATI	STABILITY
BERDUSCO, R.J., AND LANE, D.P., 1985						XXX	
BRAWNER, 1986		XXX					XXX
CAMPBELL, 1981	XXX						
CAMPBELL, 1989		XXX					
CANMET, 1977a	XXX						
CANMET, 1977b					XXX		
CANMET, 1991					XXX		
CLARIDGE, F.B., et al, 1986		XXX					
COMMITTEE ON DISPOSAL OF EXCESS SPOIL, 1981	XXX	XXX			XXX	XXX	XXX
DAS,B.M. ET.AL., 1990		XXX					
DUNNICLIFF, 1988					XXX		
GOLDER, 1986						XXX	
GOLDER, 1987	XXX			XXX	XXX		
HOLMQUIST et al, 1989	XXX	XXX		XXX			XXX
LIGHTHALL et al, 1985		XXX					
MEMPR, 1990a	XXX		XXX				
MEMPR, 1991	XXX	XXX		XXX			XXX
MESA, 1975					XXX		
MESA, 1976	XXX	XXX		XXX	XXX	XXX	
NICHOLS, R.S., 1986							
PROC. INT. SYMP ON FLOW-THROUGH ROCK DRAINS, 1986		XXX					
ROBERTSON, 1982					XXX		
SOCIETY OF MINING ENGINEERS, 1985							
STUCKERT et al, 1989							XXX
TECHNICAL AND RESEARCH COMMITTEE, 1986						XXX	
USDA FOREST SERVICE, 1990	XXX			XXX	XXX		XXX

FOR COMPLETE LIST OF REFERENCES, SEE LIST AT END OF PAPER

5. DUMP FAILURES - COAL MINES AND METAL MINES

Upon reviewing the failures reported in the questionnaire, it is immediately apparent that coal mines in British Columbia have experienced significantly more and larger failures than the metal mines. All significant failures reported in the industry survey are listed in Table 2. To determine why there is a higher failure rate at the coal mines, the basic geological environments which control the dump materials and foundation conditions at these mines were compared.

5.1 Dump Materials

Dump material at metal mines in British Columbia is typically composed of durable igneous and metamorphic rocks. The proportion of fines is usually relatively low and shear strength relatively high. Dumps of this type of material can be expected to be free draining due to the coarse particle size distribution. Metal mine dumps may also contain varying proportions of fine-grained material originating as surficial deposits and weak, altered rocks.

Dump materials in coal mine dumps usually contain a mixture of sandstone, siltstone, shale and mudstone in varying proportions. These rocks, especially the finer-grained members, are generally of low to moderate durability and are very susceptible to weathering and mechanical degradation. Grain-size distributions typically contain greater proportions of fine materials than the igneous and metamorphic rocks common at metal mines. Fine-grained materials have lower shear strength and poorer drainage than coarser-grained materials, resulting in lower stability. Coal mine dumps commonly contain fine-grained overburden materials such as colluvium derived from fine-grained sedimentary rocks.

Table 2 - Summary of Mine Dump Failures

WASTE DUMP NO.	DUMP MATERIAL		DURABILITY	INSTABILITY DESCRIPTION	PERCEIVED CAUSE OF INSTABILITY	(F)NDTN OR (D)UMP	TYPE OF MINE
	TYPE	%					
BAL-2	sandstone siltstone mudstone	73 24 2	high low-moderate moderate	89 06-35 000 m^3 90 07-10 000 m^3	high dump rate, fine, wet waste heavy precip. fine waste	D	coal
BCC-2	sandstone siltstone mudstone/shale	20-40 50 10-20	LA = 25% SD = 99% LA = 19% SD = 99% LA = 15% SD = 98%	90 05	high dump rate	D	coal
QSM-2	siltstone/sandstone till	70-80 20-30	poor	some exterior slumping of wet clay/till material	high moisture content of dump material	D	coal
BCC-1	sandstone siltstone mudstone/shale	20-40 50 10-20	LA = 25% SD = 99% LA = 19% SD = 99% LA = 15% SD = 98%	90 07	foundation failure on seam of saturated clay	F	coal
FOR-1	sandstone siltstone mudstone	25 50 25	LA = 29% SD = 99% LA = 34% SD = 98%	several	foundation failures high pore pressures	F	coal
FOR-2	sandstone siltstone mudstone	25 50 25	LA = 29% SD = 99% LA = 34% SD = 98%	88 09 - 8 000 000 m^3 multiple small failures	foundation failures high pore pressures	F	coal
FOR-4	sandstone siltstone mudstone	25 50 25	LA = 29% SD = 99% LA = 34% SD = 98%	89 11 - 2 500 000 m^3	failure within coll. beneath toe wedge	F	coal
GRH-2	sandstone siltstone mudstone/shale	5 45 50		83 03	wet waste, no toe support, poss snow on foundation Comb circular and basal failure	F	coal
GRH-3	sandstone siltstone mudstone/shale	10 70 20		89 11 - 300 000 to 500 000 BCM	foundation failure circular type	F	coal
LCR-1	sandstone siltstone shale/overburden	30-60 40-60 25-50/<5	SD = 93%-98%	88-06	failure along clay lens	F	coal

Table 2 - Summary of Mine Dump Failures - continued

WASTE DUMP NO.	DUMP MATERIAL		DURABILITY	INSTABILITY DESCRIPTION	PERCEIVED CAUSE OF INSTABILITY	(F)NDTN OR (D)UMP	TYPE OF MINE
	TYPE	%					
QCL-4	sandstone/conglomerate siltstone mudstone/coal	50 20 30	high-very high medium-high very low-low	87 07 - 5 600 000 m^3	Strain induced high pore pressure in toe of dump	F	coal
QCL-7	sandstone/conglomerate siltstone mudstone/coal	50 20 30	high-very high medium-high very low-low	small 90 03 90 05 - >1 000 000 m^3	foundation liquefaction weak sensitive foundation	F	coal
QCL-8	sandstone/conglomerate siltstone mudstone/coal	50 20 30	high-very high medium-high very low-low	90 04 - single small failure (<40 000 BCM)	weak and saturated foundation	F	coal
QCL-1	sandstone/conglomerate siltstone mudstone/coal	50 20 30	high-very high medium-high very low-low	several up to 100 000 BCM; ongoing high crest movements	steep foundation; fine wet waste; high dumping rate	FD	coal
BAL-3	sandstone siltstone mudstone	48 33 19	high low-moderate moderate	82 06 - 750 000 m^3 stopped short of creed		?	coal
GRH-1	sandstone siltstone mudstone/shale		SD = 96% SD = 85%	83 05	high pressure in dump and foundation circular failure	FD	coal
LCR-2	sandstone siltstone shale/overburden	30-60 40-60 25-50/<5	SD = 93%-98%	82 07 - 1966 platform 84 05 - 1894 platform 89 -5 = 1762 platform	steep foundation; high precip. base not toed-in; high fines content	FD	coal
LCR-3	sandstone siltstone shale/overburden	30-60 40-60 25-50/<5	SD = 93%-98%	2182 platform 2158 platform		? ?	coal
QCL-4	sandstone/conglomerate siltstone mudstone/coal	50 20 30	high-very high medium-high very low-low	83 -5 - 100 000 m^3		?	coal
EQS-1	tuffaceous volcanic gabbro/monzonite quartz latite	90 10	medium low-medium high	pre - 1982	high dumping rates causing high pore press in till foundation	F	metal

Table 2 - Summary of Mine Dump Failures - continued

WASTE DUMP NO.	DUMP MATERIAL		DURABILITY	INSTABILITY DESCRIPTION	PERCEIVED CAUSE OF INSTABILITY	(F)NDTN OR (D)UMP	TYPE OF MINE
	TYPE	%					
EQS-2	tuffaceous volcanic gabbro/monzonite quartz latite	90 10	medium low-medium high	pre - 1982	high dumping rates causing high pore press in till foundation	F	metal
HVC-4	quartz diorite sand/gravel/till silt/clay	25-30 70-75	high low-moderate	slumping, foundation spreading	weak foundation, saturated overburden	F	metal
HVC-5	quartz diorite sand/gravel/till silt/clay	25-30 70-75	high low-moderate	slumping, foundation spreading	weak foundation, saturated overburden	F	metal
ICM-5	rock till	85 15		several crest & infinite slope/toe failures since 1974	dump advanced too fast for pore pressure to dissipate in underlying clay	F	metal
PRE-2	andesite & tuff porph andesite	50 50	moderate moderate	one small failure on upper lift	not properly toed in; rotational failure through foundation	F	metal
PRE-3	andesite & tuff porph andesite	50 50	moderate moderate	3 small sloughs during early development; 1 snow dump failure	weak foundation, high pore pressure, smooth foundation bedrock	F	metal

5.2 Foundation Conditions

In general, at the metal mine sites, dump foundations consisting of compact to dense glacial tills and granular soils are common. At coal mines, foundation materials comprising colluvium and finer-grained alluvial materials (silts and clays) are widespread and typical.

Based on the questionnaire results, it is clear that there are basic general differences in the foundation conditions at coal mines compared with metal mines in British Columbia.

5.3 Loading Rates

Coal mines in British Columbia are generally large tonnage operations as compared with the smaller metal mines (with a few notable exceptions). The larger daily tonnages of dump material means that, in general, the coal mines are loading their dumps at higher rates, resulting in lower stability (see Section 7.8, Loading Rates).

5.4 Summary

It is clear that the statistically higher incidence and greater scale of failures at the coal mines surveyed are largely a result of poorer dump materials (principally higher fines content) and inferior foundation conditions (steeper and weaker). However, this is a general statement, and a wide range of conditions exist at both coal and metal mining sites in British Columbia. With a few notable exceptions, British Columbia's metal mines are loading their dumps at lower rates (due to lower daily tonnages and stripping ratios) than are the coal mines. This is also a factor to be considered.

In summary, it appears that destabilizing conditions are more common at coal mines, but each site must be considered individually so that appropriate design and operating parameters can be determined.

6. DUMP PLANNING AND RESPONSIBILITY

6.1 Summary

GENERAL

- Dump stability and performance to be reviewed by competent person with appropriate geotechnical experience.

OBSERVATIONAL METHOD

- Interaction between design and construction is very important.

PLANNING

- Planning to be carried out throughout dump life.
- Planning to indicate expected dump geometry at any time during development.
- Planning to indicate expected material distribution and phreatic conditions.
- Planning to incorporate flexibility whenever possible.

TRAINING

- Appropriate training is very important (see Table 3).

RESPONSIBILITY

- Mine manager to define responsibilities.
- Manager responsible for reporting requirements as set out in Code.
- Suggested responsibility outlined in Figure 1, details in text.

SAFETY

- Berms to be maintained on all crests.
- Dump platform to be visually monitored and maintained at appropriate grade.
- Adequate signs to be maintained.
- Lighting on night dumping areas specified.
- Safety slings are recommended.
- Roads to be maintained according to design and Code requirements.
- Safety procedures for dump toe area are outlined.

OPERATIONS MANUAL

- Mines to prepare in-house operational guidelines to deal with site-specific conditions.
- Emergency preparedness plan to form part of guidelines.

6.2 General

Mine dump construction and operation are, in most cases, carried out by mining companies as part of their daily operations. Typically the mine operations department has responsibility for the day-to-day operation and depends on mine engineering for technical assistance. A competent person with appropriate geotechnical experience, usually an engineer, will review dump stability and movement monitoring data.

Larger and more complex dumping operations may benefit from periodic review by off-site personnel. This will help to maintain adherence to accepted practices and standards. External review of dumping operations most commonly takes the form of a periodic review by a geotechnical consultant, sometimes in accordance with the requirements of the Mines Act or as a prudent measure instituted by the operators.

6.3 Observational Method

It is seldom that enough detailed information is available prior to construction for a complete, engineered design of a large mine dump.

To produce an entirely safe design, the designer would have to assume the worst possible conditions, and this approach is usually too conservative. Alternatively, assumptions may be based on available data and experience. This may be dangerous due to the number of variables and the fact that stability may be sensitive to one or more unknowns. Given the normal case in mine dump construction of a design based on limited geotechnical information, the observational method (Terzaghi and Peck, 1948; and Peck, 1969) is often the only practical approach for mine dump design and operation.

Karl Terzaghi, quoted by Ralph Peck (Peck, 1969), wrote about the observational method:

> "The procedure is as follows: Base the design on whatever information can be secured. Make a detailed inventory of all the possible differences between reality and the assumptions. Then compute, on the basis of the original assumptions, various quantities that can be measured in the field. For instance, if assumptions have been made regarding pressure in the water beneath a structure, compute the pressure at various easily accessible points, measure it, and compare the results with the forecast. Or, if assumptions have been made regarding stress-deformation properties, compute displacements, measure them, and make a similar comparison. On the basis of the results of such measurements, gradually close the gaps in knowledge and, if necessary, modify the design during construction."

This method is dependent upon the ability to modify the design and construction method or rate during construction. Mine dumps are well suited to this approach.

The observational method then, relies heavily on adequate monitoring of appropriate conditions such as movement rates, material quality, piezometric conditions and development rate.

In order to avoid excessive restrictions on operational procedures while maintaining adequate safety against mine dump failures, it is recommended that the observational method be followed.

6.4 Operations Planning

Mine rock dumps constitute some of the largest man-made structures on earth and will form significant landforms in perpetuity. It should not seem unusual that adequate planning is appropriate for these structures during all phases of development.

Mine dump operations planning should begin during the design phase and carry on throughout the life of the operation. For large dumps composed of a mix of materials whose geotechnical properties vary and may control stability, dump planning may also

affect mine planning in the open pit or underground mine. Thorough planning of the mine dump operation from site preparation to abandonment and reclamation, accounting for all related operations, will greatly mitigate potential problems and promote a safe and efficient operation.

Long-range operations planning must indicate the expected dump geometry at any time during its active life. Where inappropriate location of poor quality materials poses a threat to dump stability, material distribution within the dump must also be a part of operations planning. Mine planning aspects relating to dump operations are discussed in more detail in Section 7.3, Material Quality Control. Planning should also estimate other parameters which may threaten material dump stability such as phreatic levels in the dump and foundations and consolidation of foundation materials.

Planners should try to incorporate flexibility (e.g. maintaining alternative dumpsites, variable dump geometrics, material quality control, interaction with mine planning and scheduling to control rate and material types) wherever possible to account for changes over the entire life of the operation, which may be several years up to decades. Changes in economics, reserves or material properties might otherwise disrupt the smooth operation of the dump facility.

Appropriate training of the personnel responsible for implementing the plans is essential for effective operations (MESA, 1975). The survey of British Columbia mines indicates a range of staff training from minimal to excellent. Proper training in all aspects of dump operations for all staff concerned from dump person to mine manager will help develop an understanding of the importance of each task and thereby increase the likelihood of adherence to construction and inspection guidelines with benefits to efficiency and safety. The importance of instilling a basic understanding of general design concepts and safety hazards cannot be overemphasized. Table 3 gives a summary of needs and perceived benefits of training and education for the various groups most closely associated with mine dump operations.

TABLE 3 PERSONNEL TRAINING AND EDUCATION RECOMMENDATIONS

GROUP	NEED	BENEFIT
ENGINEERING	THOROUGH UNDERSTANDING OF ALL TECHNICAL ASPECTS OF DESIGN, CONSTRUCTION AND OPERATION. KNOWLEDGE OF GEOTECHNICAL PROPERTIES OF ALL RELEVANT WASTE AND FOUNDATION MATERIALS AND EFFECTS OF GROUNDWATER.	ABILITY TO DETECT AND RECOGNIZE ABNORMAL PERFORMANCE. ABILITY TO REACT TO CHANGES IN PROPERTIES OR DUMP PERFORMANCE RESULTING IN NEED FOR MODIFICATION OF DESIGN OR PROCEDURES. ABILITY TO SUGGEST REQUIRED CHANGES FOR REVIEW BY DESIGNER.
	KNOWLEDGE OF TYPES OF MONITORING, WHEN TO USE, AND ABILITY TO ANALYZE MONITORING RESULTS. FAMILIARITY WITH GUIDELINES PERTAINING TO MONITORING, CLOSURE, REOPENING, ETC. KNOWLEDGE OF POTENTIAL MAGNITUDE, SPEED AND EFFECTS OF DUMP FAILURE.	ABILITY TO REACT APPROPRIATELY TO MOVEMENTS OR UNUSUAL OCCURRENCES. APPROPRIATE MONITORING TECHNIQUES APPLIED TO SPECIFIC SITUATIONS.
OPERATIONS (MANAGERS AND SUPERVISORS)	THOROUGH KNOWLEDGE OF DESIGN SPECIFICATIONS.	ABILITY TO QUICKLY RECOGNIZE VARIANCE FROM DESIGN SPECS.
	BASIC UNDERSTANDING OF POSSIBLE IMPLICATIONS OF VARIANCE FROM TECHNICAL DESIGN SPECS.	MORE RATIONAL APPROACH TO CONSTRUCTION DECISIONS.
	ABILITY TO RECOGNIZE SIGNS OF INSTABILITY. KNOWLEDGE OF POTENTIAL MAGNITUDE, SPEED AND EFFECTS OF DUMP FAILURE. KNOWLEDGE OF APPROPRIATE REACTIONS TO VARIOUS SIGNS.	SHORTER AND MORE TIMELY RESPONSE TO POTENTIAL PROBLEMS. RECOGNITION OF POTENTIAL INJURY OR DEATH, INTERRUPTIONS TO OPERATIONS, ENVIRONMENTAL DAMAGE, INDUSTRY/REGULATOR RELATIONS.
OPERATIONS (OPERATORS)	ABILITY TO RECOGNIZE SIGNS OF INSTABILITY. THOROUGH WORKING KNOWLEDGE OF ALL MONITORING EQUIPMENT IN USE. KNOWLEDGE OF GOOD DUMPING PROCEDURES.	FASTER REACTIONS TO PROBLEMS DUE TO IMMEDIATE REPORTING BY ON-DUMP PERSONNEL. SAFER WORKING ENVIRONMENT DUE TO BETTER UNDERSTANDING.

6.5 Areas of Responsibility

A suggested breakdown of responsibility relating to mine dump operations is given below and illustrated in Figure 1.

Mine Manager

The mine manager is responsible for all aspects of dump operation. This responsibility will include adherence to specific procedures and design specifications as well as the keeping of accurate and meaningful records of dump construction and performance. According to rules set out in the Code, the manager must adhere to certain reporting requirements pertaining to unusual or unsafe occurrences. Delegation of responsibility by the manager is necessary to carry out the operations of the mine.

The manager will communicate with the District Inspector and appropriate consultants as required.

Mine Superintendent

The mine superintendent reports to the mine manager and is in charge of mine operations.

Mine General Foreman

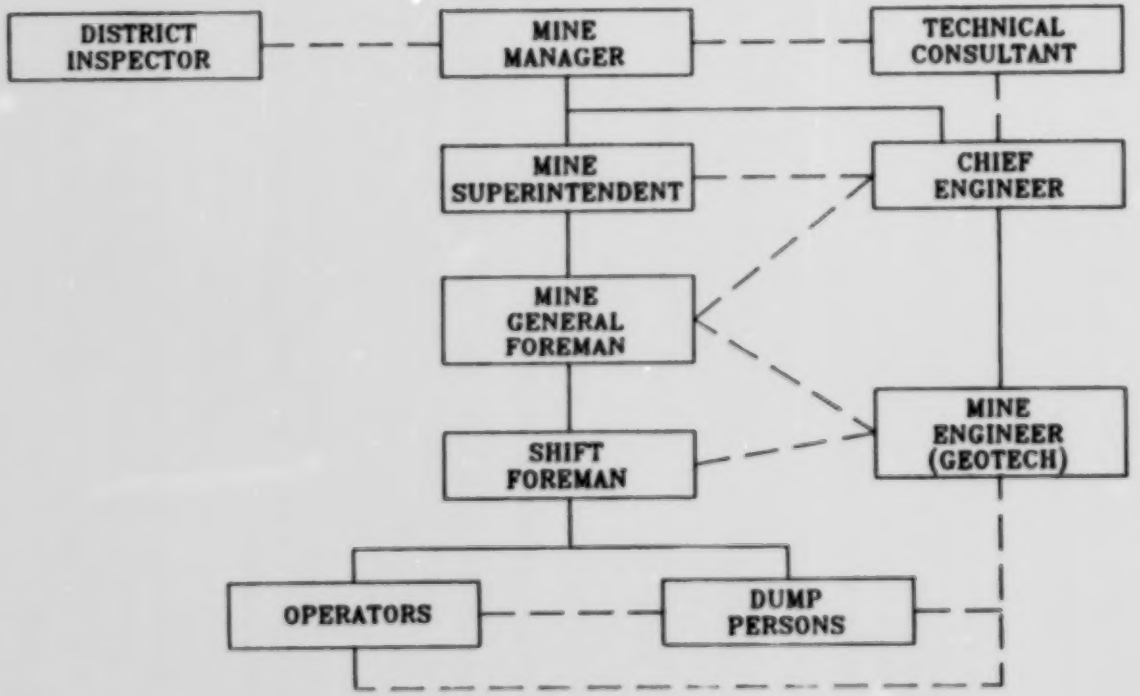
The mine general foreman reports to the mine superintendent and directs the shift foremen in their responsibilities.

Shift Foreman

The shift foreman reports to the mine general foreman and is responsible on a shift basis for dump operations. A dump log must be completed for each active dump for each shift by the foreman as required by the Code. The dump log should contain all pertinent information relating to the dump, including but not limited to the following:

- foreman's name;
- dump name;

TYPICAL RESPONSIBILITY DIAGRAM RELATING TO WASTE DUMP OPERATIONS



PATHS OF REPORTING RESPONSIBILITY AND INFORMATION EXCHANGE

PATHS OF INFORMATION EXCHANGE

FIGURE 1

- date;
- plan map based on most up-to-date survey information available with sketches relating to current and approximate crest and toe locations;
- active dumping crest length;
- monitoring instrumentation in use. Typically, this will include wireline extensometers only. Other instrumentation types are generally handled by others (e.g. survey department, geotechnical engineers);
- irregularities noted (cracking, etc.);
- any special concerns;
- approximate rate of crest advance;
- a description of the material being dumped (e.g. competent sandstone, mudstone);
- weather conditions;
- drainage and water problems;
- current restrictions or instructions, and any special instructions to dump person or equipment operators (e.g. watch for cracks developing in a particular area, or only good quality material to be dumped here); and
- conclusions regarding investigations or discussions of any special conditions brought to the attention of the shift foreman by the dump person.

The foreman must sign his report at the end of each shift and must also countersign the previous shift's report to acknowledge receipt of the information. The foreman must be made aware of any new survey or monitoring information, and this must be passed on to subsequent shifts.

The foreman should check all instrumentation (e.g. wireline extensometers) to ensure proper set-up and operations. The foreman should also be responsible for ensuring that all pertinent monitoring data is properly recorded, filed and distributed to appropriate personnel.

Dump Person

The dump person will report to the foreman and will be responsible for directing all traffic on the dump. The dump person may, where appropriate, assist the engineer to set up monitoring instrumentation such as wireline extensometers and record the resulting data.

The dump person will report immediately any unusual occurrences on the dump to the foreman.

The dump person will prepare a report for the foreman at the end of each shift, including but not restricted to the following information:

- data from any instrumentation readings;
- description of the state of the dump at the beginning and end of the shift and any changes noted during the shift (bulging on the slope or at the toe, cracking at the crest or on the dump platform, settlement of the crest or dump platform, etc.); and
- abnormal water conditions.

Chief Engineer

The chief engineer is responsible for implementing the dump designs and for technical aspects of dump planning, operation and construction. The chief engineer normally reports to the mine manager and provides technical service to the mining department. The chief engineer will oversee and direct, as necessary, the actions of the engineer responsible for the dump. The chief engineer should designate the engineer or other competent person responsible for the dump.

Engineer

The engineer or other competent person responsible (hereinafter referred to as the engineer) for the dump will have appropriate geotechnical experience and will report to the chief engineer. The engineer will review dump reports and perform periodic inspections to determine whether dumps are performing as expected.

The engineer will be responsible for reviewing mine planning and scheduling as related to mine dump operations and checking for adherence to the accepted dump design and construction guidelines. The engineer will advise mine planning and scheduling personnel on matters concerning material quality control in mine dumps. The engineer, with the assistance of the dump person, or other trained person, will set up any monitoring equipment required such as wireline extensometers. The engineer is responsible for ensuring that such instrumentation is properly set up and maintained, and that appropriate readings are taken and records kept.

The engineer will carry out analysis of dump data such as piezometer readings and movement information and make the necessary recommendations and notify personnel regarding changes required. The engineer should be fully familiar with the technical and operational aspects of the design and all relevant technical reports written for the mine.

The engineer will immediately report any significant irregularities regarding dump construction and performance to the chief engineer.

6.6 Safety

6.6.1 Berms

As discussed later in Section 7.5.1, General Dumping Rules, safety berms must be maintained on all mine dump crests.

6.6.2 Dump Platform

The condition of the dump platform must be monitored visually for any signs of instability, as discussed in Section 8.2, Visual Inspections. Also, it is the responsibility of the dump person and/or dozer operator to ensure that the surface of the dump is maintained in good condition regarding traffic movement.

The dump platform must be maintained with an uphill grade to the crest. Because of the ongoing settlements of an active dump, this will require periodic work. A grade of not less than 2% should be maintained.

6.6.3 Signs

Adequate signage should be maintained on dump platforms and access roads to ensure smooth traffic flow. Signs will be required to clearly mark active and closed dumping areas, direction of travel, crossovers, etc.

6.6.4 Dump Lighting

Most of the mines surveyed maintain lighting on the dumps for night operation. Lights should be adequate to effectively light the active dumping area. The lights should be placed in such a way as to avoid shining directly into truck operators' eyes during the approach or dumping procedure.

The American National Standard Practice for Industrial Lighting (ANSI/IES RP-7, 1984) was investigated for a practical guideline. The ANSI specification for quarries (the most relevant category) recommends 50 Lux (or 5 footcandles). It is recommended that these values be adopted as the minimum for illumination of active dump platforms.

6.6.5 Safety Slings

Safety slings, or cables, are used for emergency towing of equipment. Their use on the dump platform would be required in the event of a haul truck becoming disabled on unstable ground near the dump crest. A dozer operator would connect the cable to a suitable attachment point on the truck and proceed to tow the disabled vehicle to stable

ground as quickly as possible. Safety slings should be kept in a highly visible and accessible location close to active dumping areas. Foremen, dump persons, dozer operators and truck drivers should be familiar with locations and use of the equipment.

Material and construction of such devices must be in accordance with rules and specifications set out in the Code, Section 4.48, Rigging, and Section 4.49, Slings.

6.6.6 Roads

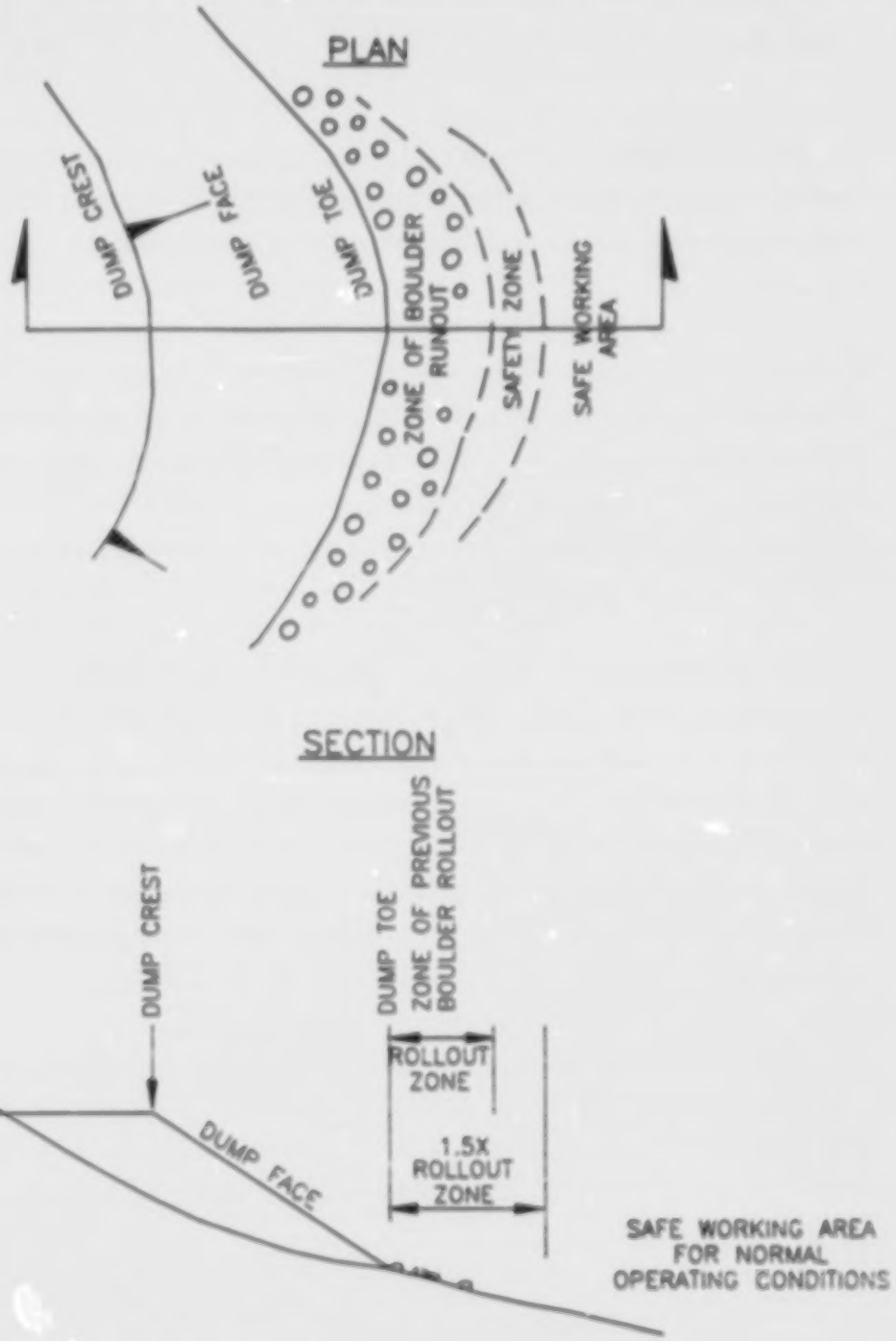
Maintenance of road conditions is beneficial for reasons of safety and vehicle maintenance. Care should be taken to remove any loose rocks from roadways. Visual inspection of roadways near dump crests should reveal any problems due to subsidence or cracking. Haul truck operators, dump persons, dozer operators and any others who routinely visit the dumps should be trained in recognition of these problems and must report them immediately to their superiors.

The reader is directed to sections of the Code pertaining to road conditions. Section 6.8 of the Code describes rules for reporting haul road types, construction methods and design parameters. Sections 6.12 through 6.12.8 of the Code give further rules for operations pertaining to haul roads on and around dumps.

6.6.7 Safety Beyond Dump Toe

6.6.7.1 Normal Operating Condition

Safety near the dump toe must be considered for both normal operating conditions and dump failure conditions. During normal dumping operation, coarse rock dumped from the crest may roll out beyond the toe. Personnel and equipment must be kept clear of the area of potential rollout for individual boulders. A safety zone beyond the line of previous maximum rollout should be determined. It is suggested that this line be stepped out from the previous maximum rollout by a distance equal to one-half the distance from the dump toe (see Figure 2).



SCHEMATIC PLAN & SECTION ILLUSTRATING SAFE WORKING AREA SETBACK FROM DUMP TOE

FIGURE 2

6.6.7.2 Dump Failure Condition

Assessment of safety beyond the toe of the dump for the case of slope failure should consider personnel and movable equipment as well as permanent or stationary installations.

Movement monitoring, as discussed in detail in Section 8, Dump Monitoring, will warn of impending failure and should give adequate time to evacuate personnel and equipment from areas of potential danger beyond the dump toe. More permanent installations which cannot be moved at short notice should be located beyond the range of potential debris from a slope failure, as discussed below. In some cases, protection berms may be considered.

The runout distance of debris from dump slope failures is highly variable and depends on a number of factors. Heim (1932) describes the sturzstrom type of failure where failure debris attains high velocities and can travel considerable distances over relatively flat ground. Various other authors have since made numerous attempts at mathematical analysis of runout characteristics. Even with specific and detailed information, accurate mathematical prediction of runout may be difficult or impossible due to the number of variables and our limited understanding of the operative mechanisms.

Campbell (1981) reported an empirical relationship between mine dump height and runout angle. This may be the best practical means to date of predicting the maximum distance of travel for slide debris. The runout angle is illustrated in Figure 18, Section 10.2, Failure Report. Campbell reported that the flattest runout angle observed was approximately 11°.

The Department of Energy, Mines and Resources Canada has recently commissioned a study to be entitled "Runout Characteristics of Debris from Dump Failures in Mountainous Terrain" (CANMET, 1992). This two-phased study will include a review of existing predictive methods and refinement and further development of prediction of runout characteristics. This work is scheduled for completion by March 31, 1992.

6.7 Manual for Dump Operation and Emergency Preparedness

Several of the British Columbia mines surveyed had prepared written manuals for mine dump operations covering such topics as dumping rules, truck and dozer procedures, dump person procedures and monitoring. These manuals vary in content and completeness but as a whole were very useful in the preparation of Sections 7 and 8 of this report.

Each mine should prepare a site-specific manual for its mine dump operations based on these guidelines. Such a manual would give details of specific procedures suited to local conditions and be in compliance with the Code.

This document should include a section on emergency preparedness and response related to mine dumps. For the site-specific conditions of the mine and its individual dumps, the emergency preparedness plan should:

- define an emergency situation. This would include the obvious event of a major dump failure but may also include the following unusual or extreme events:
  - slumping, bulging, cracking or other evidence of impending failure of the dump,
  - sudden change or increase in seepage from the dump, or appearance of cloudy water in seepage,
  - large earthquake,
  - severe storm (which may lead to failure of diversion structures),
  - blockage of creek or river by or relating to mine dump.

Particular attention must be given to inspecting and, where necessary, repairing the dump and associated structures (drainage, stream diversion, etc.) following unusual or extreme events;

- identify potential areas of danger or other concern such as:

  - runout areas for failed material,
  - areas of potential flooding due to stream blockage,
  - dump surfaces which may fail;

- define physical assets as well as human resources which may be located within danger areas; and

- clearly mandate staff responsibilities and responses under defined emergency conditions. These responsibilities should include:

  - notification of agencies such as Provincial Emergency Program (PEP) and Emergency Preparedness Canada; and
  - First Air Services - who on staff can help and how to request help from outside sources such as ambulances.

7. DUMP OPERATION

7.1 Summary

MATERIAL QUALITY CONTROL

- Material quality and distribution are very important.
- Detailed planning may be required to ensure proper distribution.
- Soil should be placed in specially designed dumps.
- Soil should not be mixed in rock dumps at ratio of less than 10 parts rock to one part soil.

MATERIAL QUALITY DEGRADATION

- Blasting and handling will affect material quality.
- Optimize blast designs to minimize excessive breakage.
- Avoid rehandling.
- Use appropriate placement methods.
- Protect traffic areas with durable material.
- Observe and document material performance.

VERIFICATION OF MATERIAL PROPERTIES

- Verify design assumptions by tests and observation of material.
- Modify design if necessary.

FOUNDATION PREPARATION

- Adequate foundation preparation, according to design to be carried out.
- Topsoil to be stockpiled if required for reclamation.

DRAINAGE CONTROLS

- Adequate drainage of all water sources to be specified in design and implemented in operation.
- Mine manager responsible to ensure design requirements are met.

SURFACE WATER CONTROL

- Keep surface water off dump as much as practical.
- Sedimentation ponds may be required.
- Consider settlement in drainage planning.

DUMPING PROCEDURES

- General dumping rules and specific procedures for equipment and personnel are specified.

ALTERNATIVE DUMP AREAS

- Maintain alternative dump areas wherever possible.

CONTROL OF SNOW

- Plan dumps in low snow areas if possible.
- Avoid dumping on snow.
- Dump snow in designated snow dumps.
- Plan dumping to minimize snow effects.

OPERATING CREST LENGTH

- Maintain maximum operating crest length to lessen loading rate.

LOADING RATES

- Loading rates are significant in many dump failures.
- Loading rate/dump height relationship is important.
- Until performance is proven, use loading rate/dump height guideline or more extensive monitoring.

7.2 General

The current state of practice of mine dump operation as determined from the written responses to the questionnaire, telephone interviews and site visits is summarized in Table 4. Although it is impossible to include all available information in a table of this nature, it presents a brief overview of the current status of operating mine dumps in British Columbia.

The Code provides rules concerning mine dump operations and other mining activities. Specific relevant sections of the Code are listed in Section 3, Mines Act and Health, Safety and Reclamation Code.

TABLE 4 DUMP OPERATIONS SUMMARY FOR BRITISH COLUMBIA MINES

MINE NAME	MINE TYPE	IN-HOUSE GUIDELINES	STAFF TRAINING	MONITORING	USE OF LIGHTS	DETAILED INSPECTIONS BY	DETAILED INSPECTIONS FREQUENCY	DUMP PERSON	SIGNIFICANT FAILURES	RECORDS KEPT
BALMER	COAL	YES	NO	VIS,WM	YES	CONSULTANT DIST INS	QUARTERLY ANNUALLY	YES	YES	WQ, CRA
BYRON CREEK	COAL	NO	YES	VIS, WM, PZ	YES	CONSULTANT DIST INS	ANNUALLY ANNUALLY	DOZER OP	YES	WQ
BULLMOOSE	COAL	YES	YES	VIS, PZ, EDM, WM	YES	CONSULTANT SITE ENG	ANNUALLY ANNUALLY		NO	WQ, CRA
FORDING	COAL	YES	YES	VIS, WM	YES	SITE ENG CONSULTANT	WEEKLY AS REQ'D	YES	YES	WQ, CRA
GREENHILLS	COAL	YES	YES	VIS, WM	NO	CONSULTANT	QUARTERLY & ANNUALLY	YES	YES	WQ, CRA
LINE CREEK	COAL	YES	YES	VIS, WM PZ	YES	CONSULTANT	AS REQ'D	NO	YES	WQ
QUINTETTE	COAL	YES	YES	VIS, PZ, EDM, WM		CONSULTANT SITE ENG	AS REQ'D DAILY	YES	YES	WQ
QUINSAM	COAL	NO	YES	VIS	YES	SITE ENG	WEEKLY	NO	NO	CRA
AFTON	METAL	NO	NO	VISUAL	NO	NONE	N/A	NO 50% DOZER OP 50%	NO	CRA
BELL	METAL	NO	YES	VIS	NO	DIST INS	AS REQ'D	DOZER OP	NO	WQ, CRA
CASSIAR	ASBESTOS		YES	VIS, CONV. SURVEY	NO				NO	
ENDAKO	METAL		YES (basic)	VIS	NO				NO	
EQUITY	METAL	YES	YES (operators)	VIS, EDM TEMP (AMD)	YES	SITE ENG	AS REQ'SD	NO	NONE IN 9 YRS	WQ(AMD)
GOLDEN BEAR	METAL	YES	YES	VIS, WM EDM	NO NIGHT OPER	CONSULTANT	ANNUALLY	DOZER OP	YES	CRA

LEGEND										
		YES OR NO	YES OR NO	TYPE WM–WIRELINE MON EDM–ELEC DIST PZ–PIEZOMETERS VIS–VISUAL		SITE ENG CONSULTANT ETC.	ANNUALLY QUARTERLY WEEKLY ETC.	YES NO OR DOZER OPERATOR	YES OR NO	CRA–CREST RATE ADVANCE WQ–WASTE QUALITY

TABLE 4 DUMP OPERATIONS SUMMARY FOR BRITISH COLUMBIA MINES

MINE NAME	MINE TYPE	IN-HOUSE GUIDELINES	STAFF TRAINING	MONITORING	USE OF LIGHTS	DETAILED INSPECTIONS BY	DETAILED INSPECTIONS FREQUENCY	DUMP PERSON	SIGNIFICANT FAILURES	RECORDS KEPT
GIBRALTAR	METAL	NO	YES	VIS, WM	YES	SITE ENG	AS REQ'D	DOZER OP	NO	WQ
VALLEY	METAL	YES	YES	VIS	YES	CONSULTANT	AS REQ'D	NO	NO	WQ, CRA
BETHLEHEM	METAL	YES	YES	VIS	YES	CONSULTANT	AS REQ'D	NO	NO	WQ
HIGHMONT	METAL	YES	YES	VIS	YES	CONSULTANT	AS REQ'D	YES	NO	WQ
LORNEX #2	METAL	YES	YES	VIS	YES	CONSULTANT	AS REQ'D	NO	NO	WQ
ISLAND COPPE	METAL	YES	YES	VIS CONV.SURVEY	YES	CONSULTANT	AS REQ'D	NO	YES	CRA
LYNX/HW	METAL	NO	NO	PZ(AMD) VIS					NO	CRA
NICKEL PLATE	METAL	NO	NO	VIS	YES	CONSULTANT	QUARTERLY	NO	NO	WQ
PREMIER	METAL	NO	NO	VIS, WM	YES	NO	N/A	YES	YES	WQ, CRA
SAMATOSUM	METAL	NO	N/A (contractor)	VIS	YES	NO	N/A	NO	NO	WQ(AMD)
SIMILCO	METAL	NO	YES	VIS	NO	NONE	N/A	YES	NO	WQ
SULLIVAN	METAL	NO		VIS					NO	CRA
SUMMARY		13 YES 11 NO	19 YES 5 NO	26 VIS 26 VIS 19 WM, 5 PZ 4EDM, 1 TEMP	16 YES 6 NO	3 DIST INS 6 SITE ENG 14 CONS 3 NO		7 YES 5 DOZER OP 18 NO	9 YES 17 NO	13 CRA 18 WQ
LEGEND		YES OR NO	YES OR NO	TYPE WM=WIRELINE MON EDM=ELEC DIST PZ=PIEZOMETERS VIS=VISUAL		SITE ENG CONSULTANT ETC.	ANNUALLY QUARTERLY WEEKLY ETC.	YES NO OR DOZER OPERATOR	YES OR NO	CRA=CREST RATE ADVANCE WQ=WASTE QUALITY

7.3 Material Quality Control

Dump material may vary considerably in its durability and strength. As engineering materials, coarse, angular particles of hard, durable rock are ideal. At the other end of the spectrum are materials with a high fines content or which have low durability and, hence, a tendency to break down with time. Material with a high percentage of weak particles, or material which deteriorates over time may contribute to a variety of problems such as permeability due to breakdown in grain size with resultant buildup of pore water, and lower shear strength. These could result in reduced dump stability.

Most mining operations encounter a range of material types in their rock and overburden materials. In some cases, strategic planning of disposal of the various materials may be necessary to minimize future problems. This planning should be directed toward placement of better quality material in such areas as:

- drainage zones (e.g. gullies, valley bottoms);
- areas requiring erosion protection (e.g. stream diversions, ditches); and
- higher sections of dumps.

Where good quality material is in limited supply, it may be required to schedule material removal from the pit according to rock quality as part of mine planning. This may require development of specific models of material quality, or at least, rock unit, e.g. specific distribution.

Every mine has some form of model of the deposit. This may be two-dimensional hand-drawn sections with interpretations of ore and waste distributions, coal seams, grade estimates, etc. It may be a two- or three-dimensional computer-based model. Initially, these interpretations of material distribution and grade or quality are based on exploration data. They should be revised and refined as more data becomes available through mining exposure and production drilling. These models should, in many

cases, be expanded to include information directly or indirectly relevant to rock dump operations, such as rock hardness, rate of drill penetration, rock type, fracturing, slake durability and grain-size distribution expected after blasting, transporting and placing, etc. Using these parameters as indicators of rock quality, specific planning and prediction of material quality distribution and its effect on stability can be carried out. Computer-based geological modelling and mine planning systems which can address these tasks are now becoming available on most minesites and are recommended for more complex material handling tasks.

Overburden (soil) should be excluded from mine dumps, as it will hinder drainage and introduce zones of lower shear strength. Overburden should be placed in specifically designated and designed dumps or stockpile sites. Where it is not possible to place overburden soil in specifically designed dumps, it may be mixed into rock dumps according to criteria given below. The intent is to mix it in appropriate proportions such that the fine-grained material can be accommodated in the voids between coarser rock particles without significant effect on the dump shear strength parameters. The soil material must be mixed with the rock material in a ratio of no less than 10 parts rock to one part soil. It should never be mixed with poor quality rock (e.g. high fines content). Variance from this guideline should be based on a specific design prepared by a professional engineer with appropriate geotechnical experience.

7.3.1 Material Quality Degradation

In mines faced with disposal of large proportions of poor quality material, particular attention must be focused on maintaining the best rock quality possible. Rock quality can deteriorate between its in situ state and its final resting place in the dump because of a number of factors. Most important among these are:

- Blasting: Blasts in poor quality rock should be designed to minimize excessive breakage and the resulting finer grain size distribution. By optimizing the blast design (a combination of amount of explosive, spacing, delay, hole diameter, pattern, depth, sequence, etc.), it has been shown that the percentage

passing the 2-inch sieve can be reduced by up to 48% (Bechtel, 1975, quoted by Holmquist et al., 1989).

- Handling and Placement: Any mechanical handling will cause some breaking of poor quality rock materials. The more handling-intensive the placement method, the more breakage can be expected. Of the commonly used placement methods, end dumping will usually cause the minimum degradation. Dumping short and dozing adds an extra degree of breakage. Designs requiring placement in lifts and those requiring compaction will suffer the effects of further degrees of breakage. Heavy equipment (e.g. dozers and haul trucks), which by necessity travels on dump surfaces, will also have a deleterious mechanical effect on the materials.

Procedures to minimize excessive mechanical action causing material degradation should be considered where poor quality materials are a potential problem. Some guidelines are given below:

- study and optimize blast designs to minimize excessive breakage;
- schedule excavation and placement to avoid rehandling of materials where possible;
- use the least mechanically intensive placement method possible within the design guidelines;
- use better quality materials to provide durable traffic surfaces in heavily travelled areas; and
- observe and document the performance of materials to gain a better understanding of their properties.

7.3.2 Verification of Material Properties

Most mine dump designs are based on the best available data concerning dump and foundation material properties, certain assumptions and engineering judgement. Depending on the level of information available, the design may be either overly optimistic or too conservative. In order to confirm crucial design assumptions, observations and tests should be carried out during operation (see Section 6.3,

Observational Method). Significant changes to basic designs may be indicated if dump and foundation material properties and behaviours are found, during operation, to vary significantly from design assumptions. These changes may be directed towards improving an overly cautious design or to avoiding possible instability.

The parameters which should be measured and verified include:

- particle size distribution;
- durability and segregation of coarse particles forming an underdrain;
- response to mechanical handling;
- physical and chemical weathering properties; and
- buildup of pore water pressures in the dump and in the foundation.

Where pore water pressure is a concern, piezometers should be installed in appropriate locations to monitor piezometric levels.

7.4 Implementation of Foundation Preparation and Drainage Controls

Depending on the situation, both foundation preparation and control of drainage may play significant roles in the performance and stability of a mine dump. Both of these concerns should be addressed in detail in the dump design (see MEMPR, 1991) and carried out in construction and operation of the dump. It is important that accurate records of as-built configurations be maintained for future reference.

7.4.1 Foundation Preparation

Detailed criteria for foundation preparation must be developed as part of the mine dump design and modified if necessary during construction based on performance criteria, such as piezometric levels, spreading of foundations, and heaving (see Section 6.3, Observational Method). Based on the survey of British Columbia mines,

it is apparent that foundation preparation varies from site to site. In some cases, no preparation was reported. As a minimum, most sites had the trees removed before dumping. In some cases, in addition to clearing, topsoil was removed, presumably to be stockpiled for later reclamation work. In other cases, stripping was performed down to glacial till. It is assumed that the stripped material was a fine-grained/low-strength soil. This material is removed to enhance stability and also for use in later site reclamation.

As a minimum, clearing of merchantable timber should be carried out. Trees must also be removed where they have been shown to adversely affect stability. If topsoil is shown to be a detriment to stability, it should be removed and disposed of in an appropriate manner (see Section 7.3, Material Quality Control) or stockpiled.

In some cases, foundation preparation may include other, more extensive remedial techniques including complete removal of surficial material, development of shear keys in weak foundation material, drainage controls (e.g. french drains), or consolidation of foundations. Strict adherence to design specifications is necessary, especially where specific foundation preparation is required. Generally, the degree of foundation preparation required will be based on economics as related to the comparative costs of alternative solutions such as changes to dump designs, dump development sequence, and rate of development.

Special safety precautions are required when personnel and equipment are working on the foundation adjacent to a dump toe (within the safety line defined in Figure 2). Dumping must be suspended and must be shown to be stable prior to any work near the toe. Foundation preparation should normally be completed well in advance of the dump toe.

7.4.2 Drainage

The control of water is a major concern in dump construction and operation. The main sources of water which must be considered in terms of drainage from and around a mine dump are as follows:

- slope runoff from above the dump;
- precipitation (rain and snow) falling directly on the dump;
- seepage from and within the dump foundations (springs); and
- for valley fill dumps, stream runoff from upstream of the dump.

The main concerns related to these various water sources are stability of the dumps, water quality downstream of the dump, and erosion of the dump.

Because many of British Columbia's mines are located in areas of mountainous terrain and high precipitation, mine dumps, by necessity, must often occupy valleys carrying streams. In order to construct the dump, water previously flowing in the valley must be conveyed either through or around the dump.

Historically, the most common solution has been to construct diversion ditches around the dump. Occasionally, culverts or decant systems have been built to carry water under a dump. Alternatively, a more recent approach has been to construct flow-through rock drains at the base of dumps. In this situation, coarse competent rock either strategically placed or naturally segregated through end dumping forms the lower part of the dump, through which the water can pass easily. Lighthall et al. (1985) and Claridge et al. (1986) report several cases where this has been carried out and present various pros and cons of the alternatives.

Internal drainage of water originating on the dump or from within the foundations may also be a major concern. Most mine dump designs assume a natural segregation of material particle size, resulting in a free-draining coarse fraction occurring along the

dump foundation. This situation is desirable to ensure that excessive pore pressures do not build up in the dump, leading to instability. In general, it is also assumed that the natural segregation of particle size will produce a filter zone such that fine particles do not migrate into the intended drainage zone. Should this happen, it is possible that the drainage zone will become plugged or blinded and its hydraulic conductivity diminished. This may result in an increase in piezometric pressures and a decrease in stability.

The development of a drainage layer with appropriate filtration can only be achieved if the material being dumped is of sufficient quality. Operators should bear these concerns in mind if a significant proportion of material is of low durability rock such as mudstone or shale. In some cases, mine planning and scheduling may extend to strategic placement of material on dumps to promote internal drainage.

Where a small dam is required to form a sedimentation pond downstream of the dump, suspended solids from the dump settle out and the downstream water quality is maintained at an acceptable standard. Such dams must be operational before beginning construction of the dump. Where chemical contamination of water is a concern, collection systems for surface water and possibly groundwater may also be required.

All of the above-mentioned drainage control measures should be adequately specified in the design of the dump. However, the responsibility will fall ultimately on the mine manager to ensure that design requirements are met.

In general, surface water flows from outside the dump area should be handled before dump construction by diversion around the dump. This will usually require hydrological studies to calculate a design flow to be handled by the diversion structures. This should be carried out as part of the dump design procedure. If surface water flows on dumps are unavoidable, contouring and ditching should be provided to channel the water. Ditches should be lined with coarse rock armouring to control erosion, designed

according to hydrological requirements. Low permeability linings to control seepage may also be required.

Inevitably, infiltration will occur as a result of precipitation falling directly on the dump surface. Ideally, this water will percolate through the dump to a high permeability base layer (formed by strategic placement or natural segregation of coarse rock), which will facilitate its exit from the dump.

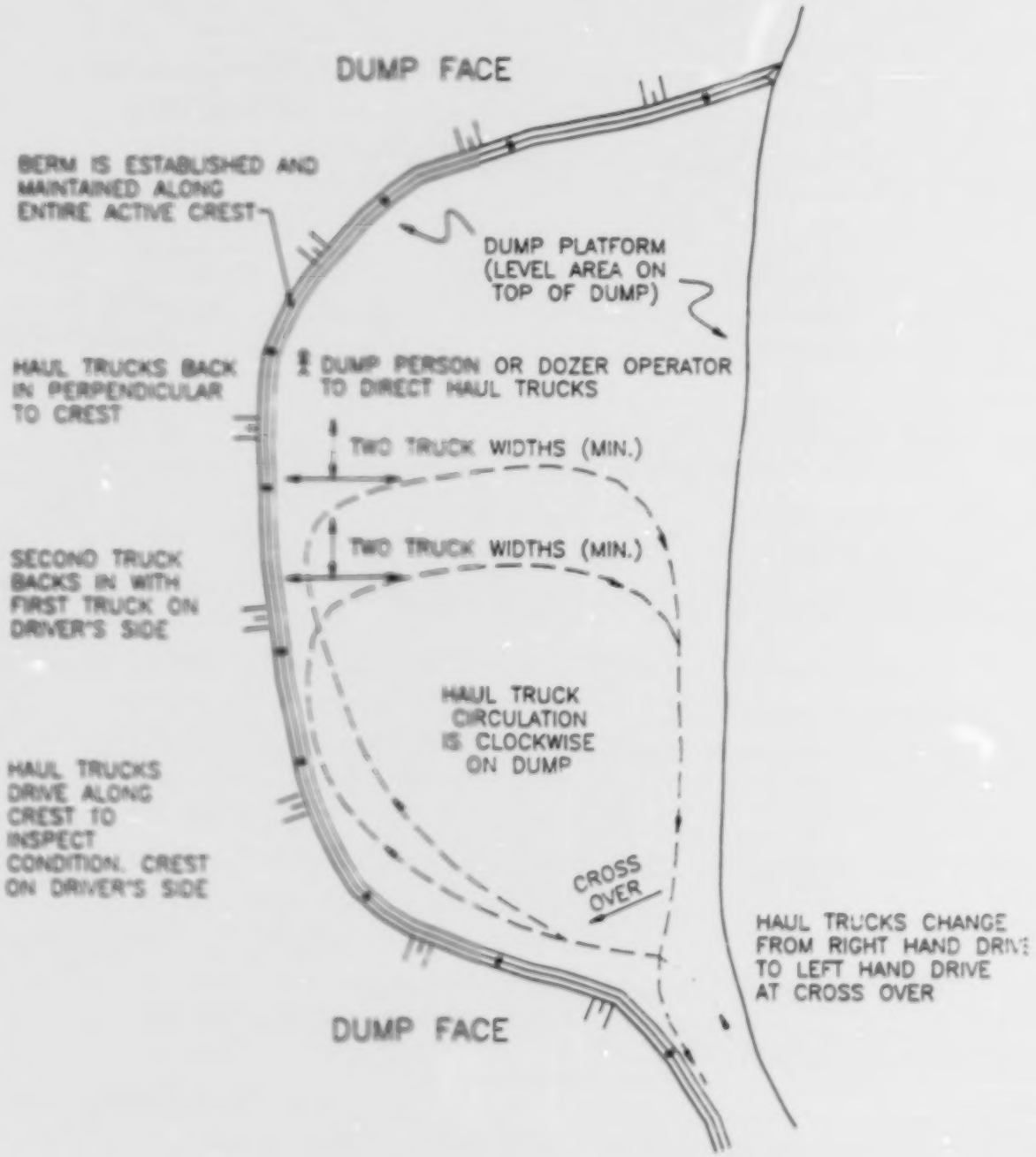
Infiltration on dump platforms can be minimized by maintaining a grade away from the crest towards the inner edge of the dump, and ditching to carry the water away. Care must be taken to ensure that water does not pond on the dump surface, or be allowed to flow into cracks formed by subsidence.

Sedimentation ponds will often be required downstream of mine dumps. Suspended solids which are picked up by surface water running over and through the dump will be trapped in the sedimentation pond.

Ongoing settlement of dumps should be considered in drainage planning. As total settlement is related to thickness, higher dump sections will invariably undergo greater settlement than lower sections. This should be taken into account when planning final dump configurations so that ultimate settlements do not disrupt planned drainage courses. These concerns should be addressed in the mine closure document (see Section 11, Monitoring and Maintenance of Old Dumps).

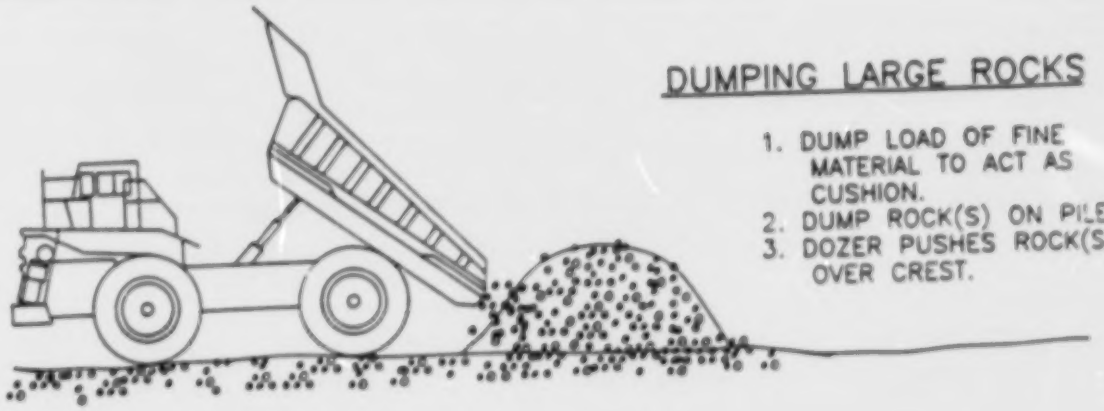
7.5 Dumping Procedures

General dumping procedures and a typical dump platform layout are illustrated in Figures 3 and 4.


DUMP FACE
BERM IS ESTABLISHED AND MAINTAINED ALONG ENTIRE ACTIVE CREST
DUMP PLATFORM (LEVEL AREA ON TOP OF DUMP)
HAUL TRUCKS BACK IN PERPENDICULAR TO CREST
DUMP PERSON OR DOZER OPERATOR TO DIRECT HAUL TRUCKS
TWO TRUCK WIDTHS (MIN.)
TWO TRUCK WIDTHS (MIN.)
SECOND TRUCK BACKS IN WITH FIRST TRUCK ON DRIVER'S SIDE
HAUL TRUCK CIRCULATION IS CLOCKWISE ON DUMP
HAUL TRUCKS DRIVE ALONG CREST TO INSPECT CONDITION. CREST ON DRIVER'S SIDE
CROSS OVER
HAUL TRUCKS CHANGE FROM RIGHT HAND DRIVE TO LEFT HAND DRIVE AT CROSS OVER
DUMP FACE

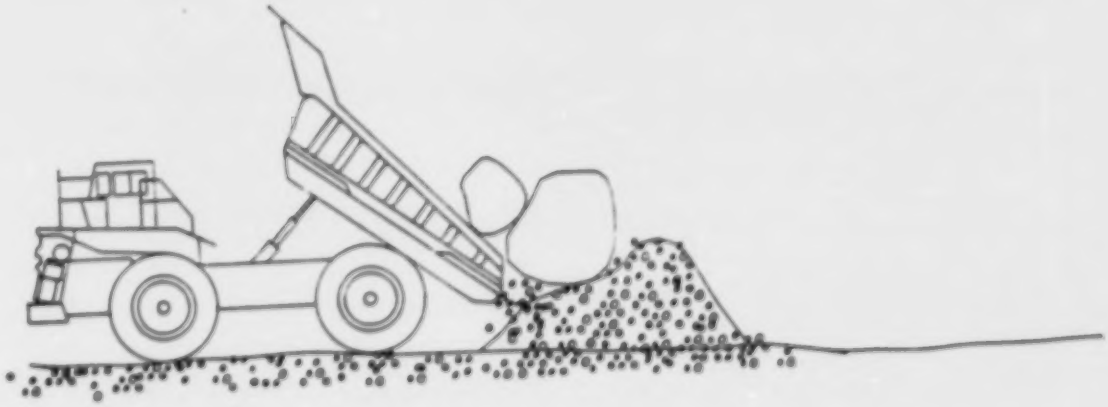
TYPICAL DUMP PLATFORM CONFIGURATION

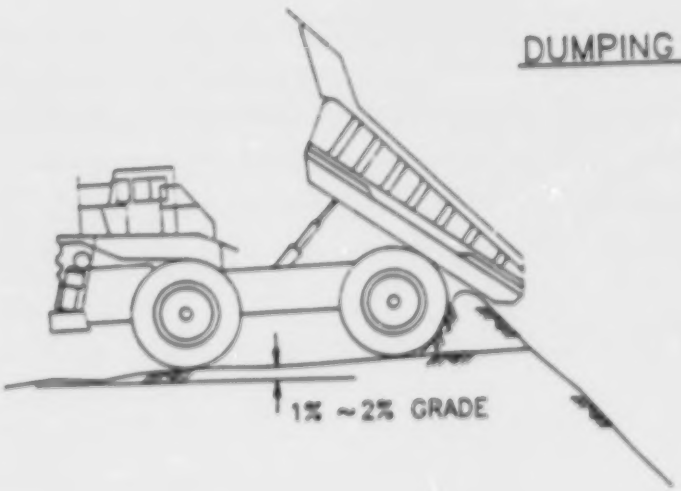
FIGURE 3



DUMPING LARGE ROCKS

1. DUMP LOAD OF FINE MATERIAL TO ACT AS CUSHION.
2. DUMP ROCK(S) ON PILE.
3. DOZER PUSHES ROCK(S) OVER CREST.





DUMPING OVER CREST

DUMPING CONFIGURATIONS

FIGURE 4

7.5.1 General Dumping Rules

- In general and unless a variance to the Code has been granted by the District Inspector, a dumping person will be required at each dumping location. The responsibilities of the dump person are detailed in Section 7.5.4, Dump Person Procedures.

- Where the dump point is more than 3 m high, the Code specifies that no dumping over the bank or within 3 m of the crest is allowed unless there is a safety berm in place and a dump person is directing vehicles to the dump point.

- The height of the berm should be at least equal to the radius of the largest haul truck wheels (half of the wheel height) as specified by the Code.

- The safety berm is intended as a guide and should not be considered a back stop to back against.

- The dump profile should be configured and maintained with a positive grade up to the crest to avoid having trucks back downhill to the dump point (Code). Dump surfaces should be graded to about 2% grade. Specific rules regarding ramping down are given in the Code.

- When two or more trucks are being dumped at the same time, they should maintain at least two truck widths' clearance between them.

- If there is no one acting as dump person on the dump, then trucks must dump their loads short of the crest to be pushed over the edge by a dozer (Code).

7.5.2 Haul Truck Procedures on Dump

- When a dump person is assigned to a dump, haul trucks will be directed by the dump person while on the dump platform.

- Haul truck circulation should be in a clockwise direction on the dump platform to provide drivers with an unobstructed view of the dump crest prior to backing in.

- When approaching the dumping area, the driver must slow the truck and check the area for berm and floor conditions, personnel and other vehicles. The area must be safe and clear before reversing.

- Haul trucks will pull in forward, then reverse back to the dump point as directed. Backup distances should be kept to a minimum.

- Haul trucks should be oriented essentially perpendicular to the berm when dumping their loads.

- Generally, oversize rocks should be dealt with in the pit by secondary blasting. However, should haul trucks arrive at the dump with such oversize material, the following recommendations are given. Loads consisting of large rocks must not be dumped over the edge. This is unsafe and may damage equipment. Such loads must be dumped short (according to the following procedure) and pushed over the edge (see Figure 4):

    - first, a load of finer material must be dumped to act as a cushion for the large rocks;
    - the oversize load should then back up to the pile of fine material;
    - the dump person should signal the truck to stop as the box of the truck is aligned with the top of the pile;
    - the truck will then dump the large rock(s) on top of the pile of fines;
    - when the truck has left the area, the dozer should push the material over the edge; and

- throughout this procedure, the dump person should stand well clear as larger boulders may have a tendency to roll.

- Loaded trucks have right-of-way.

- Trucks will reverse up to the berm only when signalled by the dump person.

- Trucks will not pull away from the berm until the box has been lowered.

- Loads should be dumped one at time. A second truck should not back up to the berm until directed to do so by the dump person and after the first truck has lowered its box and moved out.

- Trucks should not move forward or back when the box is in any position other than fully lowered.

7.5.3 Dozer Procedures on Dump

Dozers are used on the dump to maintain the dump surface and the safety berm and to push material over the edge as required.

When required, one or more loads will be dumped short of the crest to provide material for building and maintenance of the berm or the dump surface and grade.

In some cases, a variance may be granted whereby the dozer operator directs truck traffic on the dump in lieu of a dump person. In this case, a clear set of signals must be defined such that the dozer operator's intentions can be communicated unambiguously to haul truck operators.

It is incumbent on the mine manager to ensure that the dozer operators acting as designated dump persons adhere to the requirements regarding direction of traffic and hand signals laid out in Section 7.5.4, Dump Person Procedures. This requires that the dozer operator climb off the dozer when directing traffic.

7.5.4 Dump Person Procedures

By proper direction of traffic and dumping operations, the dump person contributes to the safety and efficiency of the dump. Maintaining a constant presence on the dump makes the dump person the ideal candidate to maintain surveillance of the dump and monitor equipment for development of any unusual signs which may warn of impending failure. In cases where special safety equipment is in use, the dump person may also be responsible for checking and maintaining it.

Some general guidelines for dump persons are given below.

- In addition to any standard safety equipment, the dump person should be equipped with the following: fluorescent orange vest, safety glasses, flashlight with red cone, ear plugs, and dust mask (if required). A two-way radio is also recommended.
- Where emergency cables (safety slings) for towing trucks are kept on the dumpsite, these should be checked at the beginning of each shift.
- The dump person should always work on the operator's side of the truck.
- The dump person should never attempt to cross in front of or underneath a haul truck. Cross behind a truck with extreme caution and only under the following circumstances: the truck operator is aware of your intentions and the truck is moving forward or is stopped.
- While dumping a truck, the dump person should be standing at least two truck widths away from the truck and in clear view of the operator.
- Watch for falling rocks as the box is lifted to dump the load.

A consistent set of hand signals must be adopted for use by the dump person for directing traffic and dumping operations. To avoid ambiguity and confusion, this set of hand signals must be well understood and used exclusively by all concerned. Following is a recommended set of signals (see Figure 5) derived from those in use at mines responding to the survey.

- Back the truck up. Extend the right arm fully to the side and rotate in a circular, clockwise motion. Slow down the arm motion as the truck nears the required dumping location.

- Back to the left. Stop the circular motion and extend the right arm to the left in front of the body. When the direction of travel has been sufficiently corrected, resume the circular motion, as above.

- Back to the right. Stop the circular motion and extend the right arm forward and to the right. When the direction of travel has been sufficiently corrected, resume the circular motion, as above.

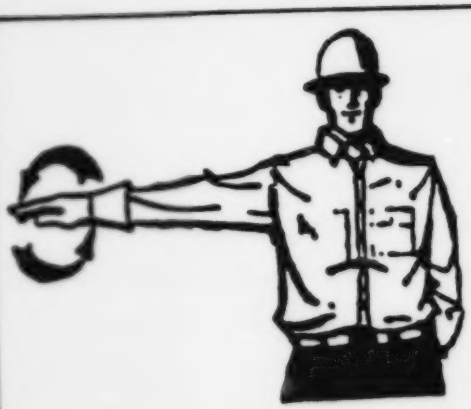
- Stop. When the truck has reached the dump position, or must stop for any other reason, with the right arm fully extended to the side, move it up and down several times to indicate to the driver to stop.

- Dump the box. When the truck has stopped in the correct position, signal the operator to dump the box by raising the right arm straight up.

- Drive forward. To indicate to the truck driver to drive forward, hold the left arm out horizontally, pointing in the desired direction of travel.

7.6 Alternative Dump Areas

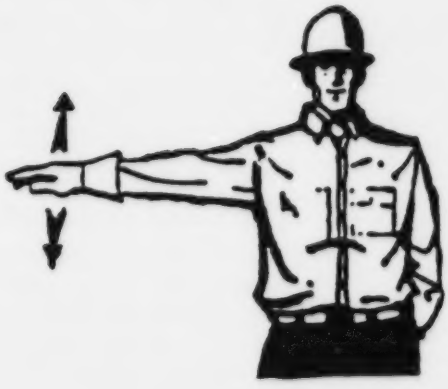
To ensure flexibility, the maintenance of as many alternative dumping areas as practical is recommended. In cases where dumps are marginally stable and must undergo temporary shutdown from time to time, the availability of alternative dumping locations will be especially important.



BACK THE TRUCK UP

BACK TO THE LEFT

BACK TO THE RIGHT



STOP

DUMP THE BOX

DRIVE FORWARD

HAND SIGNALS FOR USE BY DUMP PERSON DIRECTING HAUL TRUCKS

FIGURE 5

Situations may arise where no practical alternative dumping area is available. A possible solution to this dilemma is to dump a lift on top of the current dump platform. Of course, a careful assessment of the instability is required to ensure that this dumping is carried out only on stable areas of the dump, well removed from the area of instability. An illustration of this option is given in Figure 6.

7.7 Control of Snow

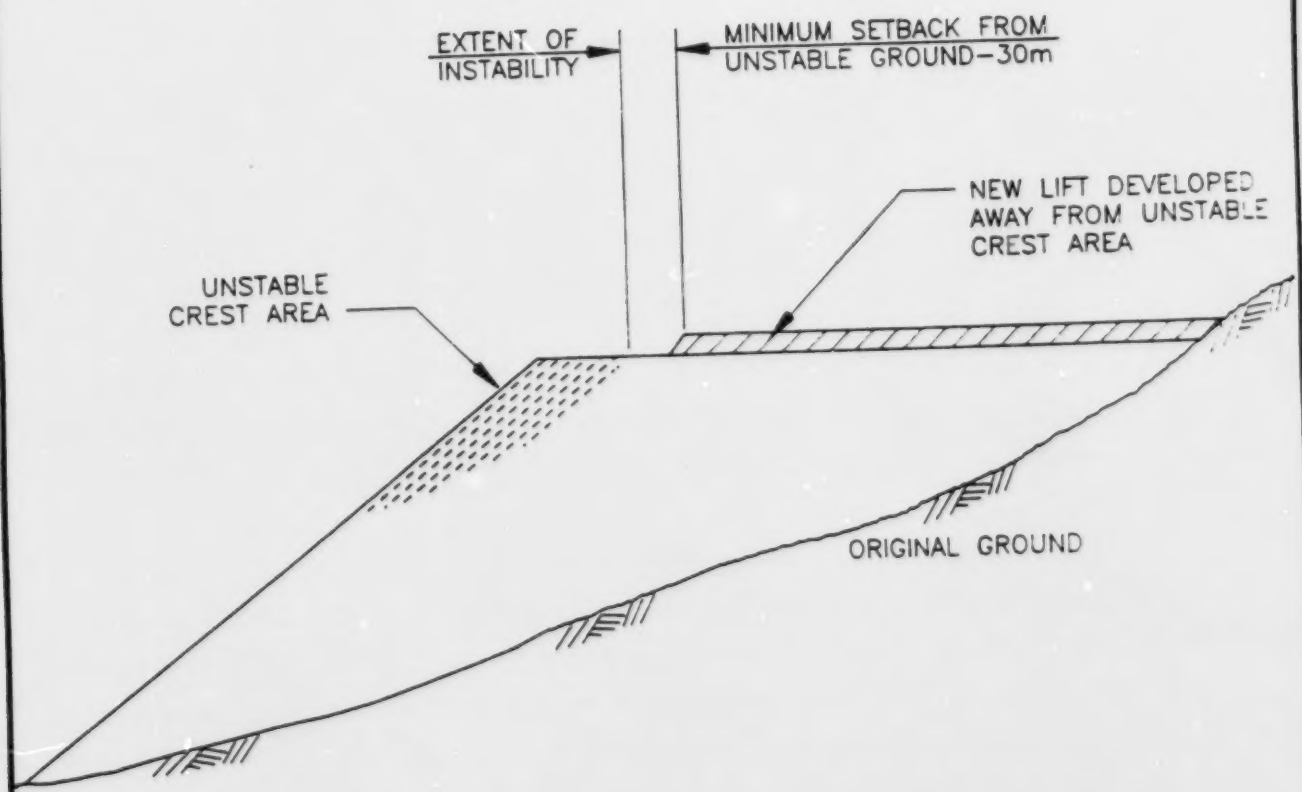
Many of British Columbia's mines are located in areas of high annual snowfall. Besides the obvious operational difficulties presented by large falls and accumulations of snow, there are significant geotechnical concerns to be considered.

Snow buildup on the dump face, either through snowfall accumulation or dumping, or both, is to be avoided. Burial of snow layers or lenses may lead to weak zones in the dump and subsequent instability.

Typically, shallow snow on the dump face will be mixed with dump material and as newly dumped rock slides down the dump face will fill the interstitial space between rock particles. This situation will generally not lead to any destabilizing effects. However, snow of depth sufficient to maintain a discrete and through-going layer or lens in the dump may lessen dump stability. This situation usually becomes most critical when the included snow begins to melt.

Tolerable depths of snow on the dump face will vary depending on the gradation of particle size in the dump material and possibly other parameters such as degree of compaction of the snow, but no general rule is available.

In areas of very high snowfall or where significant depths accumulate on leeward slopes, dump planning may require seasonal adjustments to avoid snow-related problems. For new mines, where site-specific data is not available, information can be gathered from several sources. Air photos from different times of the year can give an


EXTENT OF INSTABILITY
MINIMUM SETBACK FROM UNSTABLE GROUND–30m
NEW LIFT DEVELOPED AWAY FROM UNSTABLE CREST AREA
UNSTABLE CREST AREA
ORIGINAL GROUND

ALTERNATIVE DUMPING LOCATION–BUILDING LIFT ON STABLE DUMP PLATFORM

FIGURE 6

indication of snow accumulation patterns. In general, snow will be deeper on northeast- to northwest-facing slopes and on leeward slopes with respect to prevailing winter winds.

Snow removed from the dump platform or other areas should be placed in designated snow dumping sites separate from active or planned dumping areas.

When a situation arrives where no snow-free dumping area is available, several possible solutions may be available. Some of these are discussed below:

- dump on lower sections of the dump where stability is less critical;
- dump in areas which afford a greater stability through some physical keying or confinement (e.g. gullies);
- dump at the end of a side hill fill dump, extending the dump parallel to the valley. Thus, the snow-covered surface will possibly be oriented in such a way as to less critically affect stability; and
- dump on the horizontal surface of the dump platform to form a lift (see Figure 6). It is preferable to scrape snow from the surface prior to this operation.

7.8 Loading Rates

Crest loading rates reported by questionnaire respondents were given in terms of volume dumped per linear metre of crest per day (m^3/m/day) or in metres per day (m/day) of crest advance. Generally, metres per day of crest advance is a more useful figure and should be adopted as the reported value.

End-dumped material will initially settle in a fairly loose state on the dump face, to be buried by subsequent dumping. As dumping continues and overburden stresses increase, the material will invariably assume a denser configuration with a higher shear

strength. Thus, settlement of the dump surface and crest is inevitable and necessary for ultimate stability.

It is clear from studying case histories of mine dump failures that there is an important relationship between crest loading rates and stability. However, it is also clear that other factors are involved in each case, making it more difficult to cite specific loading rate guidelines. Other key factors include dump height, foundation material and slope, piezometric conditions and dump material quality. Of these, piezometric conditions, dump height and material quality seem to be particularly interrelated and important. The following relationships regarding these parameters are apparent:

- Piezometric Conditions: Rapid loading of saturated fine-grained material increases piezometric levels, resulting in a decrease in effective stress. Given time, or slower rates of loading, the soils will consolidate, allowing dissipation of pore pressures and transfer of stress to soil particles, thereby increasing effective stress and stability. This factor has been documented as contributing to failure in some significant dump failures in British Columbia.

- Dump Material: End-dumped material will initially settle in a fairly loose state on the dump face, to be buried and loaded by subsequent dumping. As dumping continues, overburden stresses increase and the material will invariably assume a denser condition. This denser state is more stable due to the resultant higher shear strength parameters.

  If dumping is carried out at high rates, the dump material may not have adequate time to develop a sufficiently dense condition and consequent strengthening to withstand the increasing shear stresses which will also develop in the slope. This factor may contribute to failures associated with high rates of crest advance.

- Dump Height: For a given rate of crest advance (m/day), a higher dump involves more material. Hence, the stress increase and the rate of change of stress in both the foundation and dump material are higher.

In an effort to determine meaningful guidelines for dumping rates, despite the large number of variables involved, the relationship between dump height and rate of crest advance stands out. A study was carried out of all data collected from the questionnaires to investigate this relationship. Table 5 summarizes the data for all dumps where both loading rate and dumping height were reported. The dumps were numbered (1 to 36) for reference to points plotted on the graph in Figure 7. The total volume is shown to give an indication of overall size. The questionnaire results include overall dump height, maximum vertical dump thickness, maximum bench height and lift thickness. Lift thickness is considered the most relevant of the height parameters given as it is the most recently dumped material which is of concern. This recently dumped material will have adverse effects on stability because of the conditions discussed earlier in this section relating to settlement and pore pressure.

Figure 7 is a plot of crest rate advance (m/day) versus maximum dumping height. There is no immediately obvious separation of stable and unstable dumps. However, it is possible to draw a curve (labelled "lower bound of most failures") such that most (all but three whose causes can be attributed to other extreme conditions) failed dumps fall above and most stable dumps fall below the line.

As a guideline for new mines or dumps with no performance history upon which to base dumping rate limits, the initial relationship of dumping rates and dump height should be governed by the second curve, labelled "guideline" on Figure 7. This curve has been offset from the lower bound curve to offer a degree of extra safety. This is felt necessary at this time due to our as-yet limited understanding of the complex relationship of the factors involved. As more data becomes available, it may be possible to revise the criteria for a particular dump based on its proven performance. The fact that some stable dumps plot above this guideline illustrates this point. However, had the dumps which did fail been restricted by this guideline, it is likely that some if not most of the failures could have been avoided.

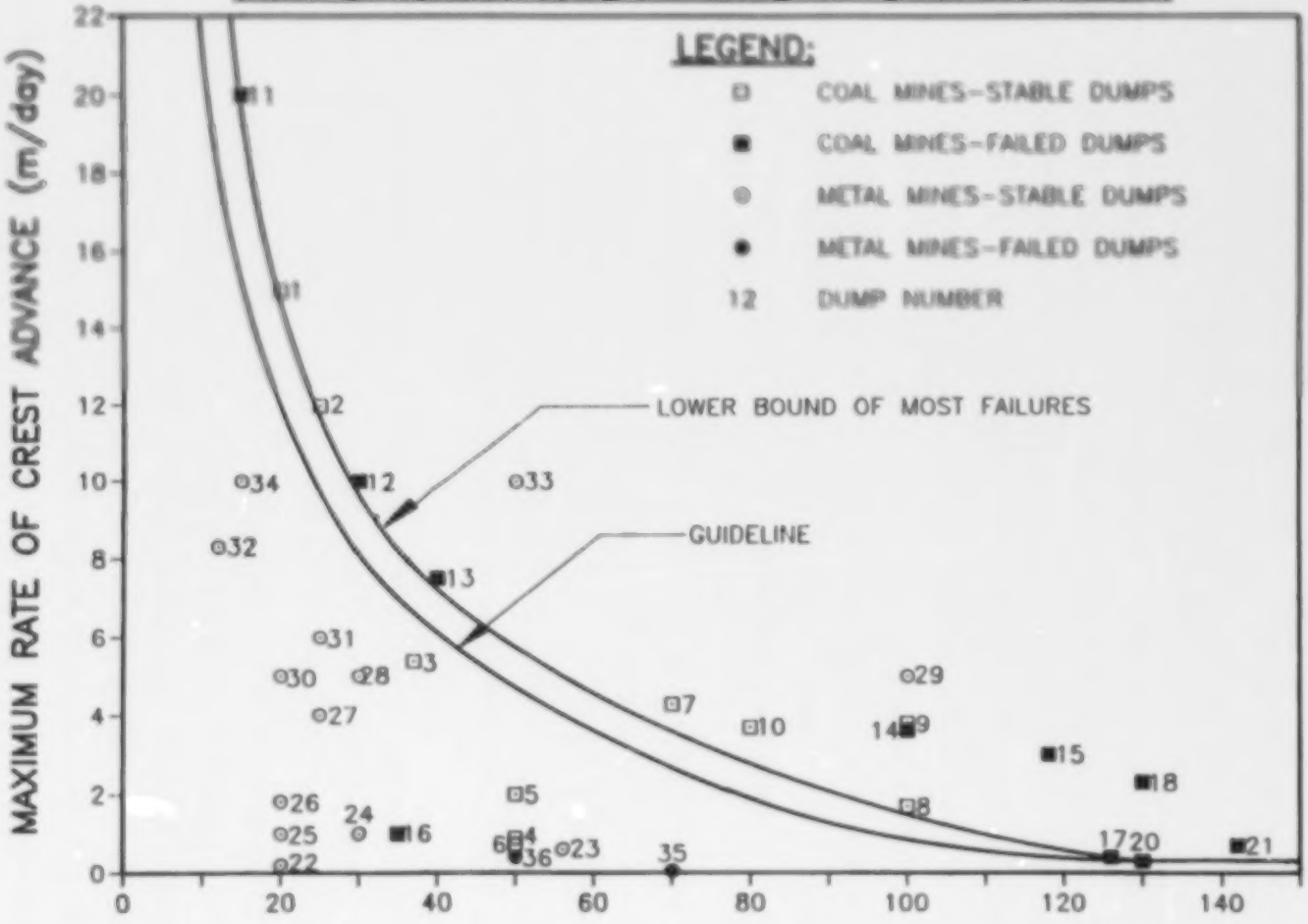
TABLE 5 CREST RATE ADVANCE vs DUMPING HEIGHT DATA

DUMP NAME	DUMP NUMBER*	COAL OR METAL	VOL (m³)	SLOPE (deg)	MAX HT (m)	MAX THICK (m)	MAX DUMPING HEIGHT*** (m)	RATE OF CREST ADVANCE		SIG. FAILURES
								m³/m/day	** m/day	
QCL-6	1	COAL	30	28	106	60	20	300	15.0	NO
QCL-2	2	COAL		37	140	25	25	300	12.0	NO
BAL-4	3	COAL	1	37	46	37	37	200	5.4	NO
SUL-1	4	COAL	20	28	230	110	50	47	0.9	NO
SUL-2	5	COAL	0.85	36	100	40	50	100	2.0	NO
SUL-5	6	COAL	40	28	150	140	50	33	0.7	NO
QCL-5	7	COAL	0.92	37	120	70	70	300	4.3	NO
BAL-5	8	COAL	25	21	265	100	100	170	1.7	NO
FOR-3	9	COAL	19.6	37	120	100	100	370	3.7	NO
QCL-3	10	COAL		37	180	80	80	300	3.8	NO
QCL-7	11	COAL	3.7	16	45	40	15	300	20.0	YES
QCL-1	12	COAL	10	37	250	120	30	300	10.0	YES
QCL-8	13	COAL	0.14	37	40	30	40	300	7.5	YES
BAL-2	14	COAL	28	37	312	100	100	358	3.6	YES
GRH-1	15	COAL	4	23	168	80	119		3.0	YES
GRH-2	16	COAL	0.7	38	160	35	35		1.0	YES
FOR-1	17	COAL	20	37	185	126	126	55.6	0.4	YES
QCL-4	18	COAL	15	37	250	150	150	300	2.3	YES
BAL-3	19	COAL	140	37	274	230	250	626	2.5	YES
FOR-2	20	COAL	80	37	360	130	130	34.3	0.3	YES
FOR-4	21	COAL	14.9	35	413	142	142	95	0.7	YES
MYR-1	22	METAL	0.54	43	50	30	20	3	0.2	NO
ICM-1	23	METAL	3.8	37	56	56	56		0.6	NO
SUL-1	24	METAL	0.7	37	30	30	30		1.0	NO
CAS-2	25	METAL	55	38	30	20	20		1.0	NO
ICM-3	26	METAL	2.1	30	20	20	20		1.8	NO
BEL-2	27	METAL	2.8	20	30*	50	25	100	4.0	NO
PRE-1	28	METAL	1.5	37	30	30	30		5.0	NO
PRE-3	29	METAL	0.31	37	100	50	100		5.0	NO
PRE-4	30	METAL	0.8	37	20	20	20		5.0	NO
BEL-3	31	METAL	4.1	15	42	35	25	150	6.0	NO
BEL-4	32	METAL	4	31	40	45	12	100	8.3	NO
PRE-2	33	METAL	1.5	35	70	70	50		10.0	NO
BEL-1	34	METAL	6.3	25	40	35	15	150	10.0	NO
ICM-5	35	METAL	242	35	91	70	70		0.0	YES
GBR-1	36	METAL	0.4	38	150	50	50	27	0.4	YES

* DUMP NUMBERS CORRESPOND TO LABELS ON PLOT IN FIGURE 7.

** WHERE CREST RATE ADVANCE WAS GIVEN IN TERMS OF m³/m/day, m/day WAS CALCULATED BY DIVIDING BY MAXIMUM DUMPING HEIGHT.

*** MAXIMUM DUMPING HEIGHT IS MAXIMUM DUMP HEIGHT IF DUMP DEVELOPED IN ONE LIFT, OR LIFT HEIGHT IF DUMP DEVELOPED IN LIFTS.



NOTES:

16. FAILURE DUE TO WET MATERIAL, NO TOE SUPPORT AND POSSIBLE SNOW ON FOUNDATION.
35. FOUNDATION FAILURE IN RAPIDLY LOADED, NORMALLY CONSOLIDATED, MARINE CLAY (MARINE DUMP).
36. REACTIVATION OF OLD LANDSLIDE. HIGH PORE PRESSURES IN FOUNDATION.

FIGURE 7

There may be special cases for which the guideline can not be practically applied. For example, the curves in Figure 7 indicate restrictions on dumps with dumping height over 140 m, and that for dumps approaching 140 m in height, the allowable dumping rates may be very low. For these cases, a more rigorous inspection and monitoring program will be required than that normally required (see Section 9, Monitoring, Inspection, Reporting and Record Keeping Requirements). These extra measures must be defined by an engineer with appropriate geotechnical experience after a review of the site conditions and all pertinent data.

Also to be considered with reference to loading rates are the relationships between overburden stress and shear strength properties and the changes in these properties due to shear strain and the related degradation of constituent particles.

Other conditions which appear to have a major effect on crest displacements and failure include time of year (e.g. spring thaw), piezometric levels, precipitation, material type, dump height, blast-induced or seismic vibration, foundation slope, and foundation material. As well as recording dumping rates and crest displacements, these other parameters should be noted as one or more of them may significantly affect stability.

By keeping accurate and detailed records, it should be possible to determine correlations between loading rates and crest displacements for specific sites and combinations of conditions. This would allow a refinement of the site-specific loading guideline. Plotting all relevant data against the calendar (horizontal axis) is suggested as a first step in analysis. Combined graphical presentation of numerical data usually facilitates meaningful interpretation. The intent is to determine correlations between movement rates and other recorded conditions in order to prepare guidelines for safe dumping. Due to the highly site-specific nature of these relationships, attention must be given to determining meaningful guidelines for individual dumps. Further discussion on this topic and example plots are presented in Section 8, Dump Monitoring.

7.9 Operating Crest Length

As discussed above, crest loading rates may have a significant effect on dump stability. By maintaining the maximum operating crest length, or using alternative dumping areas (see Section 7.6, Alternative Dump Areas), crest loading rates will be minimized and stability concerns diminished accordingly. Also, should certain areas require closure from time to time, a longer operating crest length will allow more flexibility in dealing with such concerns.

8. DUMP MONITORING

Mine dump movement monitoring, other than visual observation, is generally used at mines which have one or more of the following conditions:

- high dump faces;
- steeply sloping foundation;
- low shear strength dump materials;
- low factors of safety against failure; and
- history of instability or failure.

In British Columbia instrumented dump monitoring is carried out at many of the mines (see Table 4), particularly those in mountainous terrain.

This section presents general information and discussion on the needs for mine dump monitoring. Guidelines for monitoring requirements are presented in Section 9, Monitoring, Inspection, Reporting and Record Keeping Requirements.

During mine dump construction, internal deformations take place due to changes in total stresses and pore pressures and due to creep or secondary effects. Foundation movements and other factors influence the deformations. These deformations may result in settlement of the material or as shear displacement along a failure surface. Settlement of the dump material is not necessarily indicative of slope failure whereas shear displacement is (Robertson, 1982).

The reasons for observing mine dump deformations are:

- safety of personnel and equipment;
- understanding and predicting dump behaviour; and

- to provide information for modifying current designs or for future dump designs.

Failures of mine dumps are almost always preceded by warning signals such as increased rate of deformation, strain discontinuities, cracking of the dump platform or pore pressure buildup in the dump or foundation. These same warning signs may also appear when failure is not imminent. In order to detect significant changes in rates of deformation, and to evaluate probable causes and consequences of such changes, the following steps are required:

- install instrumentation to measure deformations and pore pressures during and after construction;
- make periodic observations (the frequency depending on factors such as construction activity and rate of movement);
- summarize and evaluate the data; and
- promptly report any deviations.

8.1 Understanding Monitoring

To most operations personnel, the need for safety is obvious, but the more technical requirements involved with proving the design, although closely tied to safety, may not be as clear. To illustrate this point, a haul truck operator would not need to be told to stay off a visibly cracked and highly deformed section of dump crest, especially if he had seen the results of past dump failures. However, if the same operator were told, "Stay off the 1590 platform because foundation piezometric pressures are increasing", he may not show the same respect, even though a much larger failure might be imminent.

Similarly, visual observations made by operations staff spending most of the working day on the dump could be very important if there is a knowledge of what to look for. As a minimum, staff should be aware of the most common types of failure and related

diagnostic signs of possible problems (see Table 3). Table 6 presents a summary of the most common mine dump failure modes, descriptions and warning signs.

8.2 Visual Inspections

Visual observations are critical to maintaining a safe dumping operation. Visual indicators of problem areas in a dump are:

- excessive surface cracking;
- safety berms will not stay in place;
- surface buildup required;
- bulging of the dump face; and
- toe or foundation creep.

These observations are important in order to implement proper dumping practices and should be correlated with instrumentation readings.

Visual inspection is the most common and often the most practical method of dump monitoring. Engineering, survey and operations staff as well as equipment operators and dump persons may visit the dump frequently or spend significant time there. These people should be trained to look for and recognize signs of instability.

8.2.1 Dump Crest

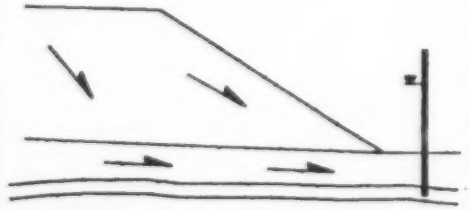
Regular visual inspections of the dump crest can detect early signs of instability such as:

- loose rock or minor slumping formed during settlement of material;

TABLE 6 FAILURE TYPES, CAUSES AND WARNING SIGNS

FAILURE TYPE	DIAGRAM	USUAL CAUSE	LIKELY EFFECTS	WARNING SIGNS
SLIVER FAILURE		OVERSTEEPENED CREST DUE TO HIGH FINES CONTENT, RAPID DUMPING RATE, WET MATERIAL.	SMALL SCALE CREST FAILURE, SUBSIDENCE AT CREST OF DUMP.	CREST CRACKING, SUBSIDENCE NEAR CREST, STEEP SLOPE BELOW CREST, INCREASING CREST DISPLACEMENT RATES.
FOUNDATION FAILURE		WEAK MATERIAL IN FOUNDATION, RAPID LOADING RATE, HIGH PORE PRESSURES IN FOUNDATION, BLASTING OR EARTHQUAKE EFFECTS.	CAN CAUSE LARGE FAILURE INVOLVING SIGNIFICANT PART OF DUMP.	SEEPAGE AT THE TOE, BULGING OR SPREADING OF DUMP TOE, CRACKS WELL BEHIND DUMP CREST.
OVERALL FAILURE		WEAK MATERIAL ALONG BASE OF DUMP(SO LAYER OF SOIL), POOR DRAINAGE ALONG BASE OF DUMP, STEEP FOUNDATION, RAPID LOADING RATE.	ENTIRE DUMP FAILS ALONG BASE.	CRACKING OF DUMP SURFACE BACK AS FAR AS CONTACT WITH GROUND, SETTLEMENT OF ENTIRE PLATFORM.
ROTATIONAL FAILURES		WEAK MATERIAL IN DUMP OR FOUNDATION, HIGH PORE PRESSURES, RAPID LOADING RATES. MAY INVOLVE DUMP MATERIAL ONLY OR ALSO INCLUDE FOUNDATION. MAY BE CIRCULAR OR NON-CIRCULAR IN CONFIGURATION.	CAN CAUSE FAILURES INVOLVING MAJOR PART OF DUMP. MAY INVOLVE DUMP ONLY OR DUMP AND FOUNDATION (TWO TYPICAL FAILURE SURFACES ILLUSTRATED).	BULGING AT TOE, CRACKING AND SETTLEMENT WELL BEHIND CREST, ROCK NOISE, POSSIBLE SCARPS WELL BEHIND CREST.

TABLE 6 FAILURE TYPES, CAUSES AND WARNING SIGNS

FAILURE TYPE	DIAGRAM	USUAL CAUSE	LIKELY EFFECTS	WARNING SIGNS
TOE FAILURE		WEAK FOUNDATION MATERIALS AT TOE, HIGH PORE PRESSURES AT TOE, STEEP SLOPES AT TOE, RAPID LOADING RATE	LOSS OF SUPPORT OF TOE, MAY LEAD TO PROPAGATION OF FAILURE UP-SLOPE	SPREADING OF TOE, YIELDING AND BULGING OF FOUNDATION SOILS AND/OR DUMP MATERIAL AT TOE.
FOUNDATION LIQUEFACTION		SILTY TO SANDY MATERIAL IN FOUNDATION, POSSIBLY CONFINED BY AQUITARDS, PORE PRESSURE BUILD-UP DUE TO RAPID LOADING. SEISMIC FORCES MAY BE IMPORTANT.	POSSIBLE MAJOR FAILURE OF SIGNIFICANT PORTION OF THE DUMP WITH LARGE RUNOUT DISTANCE. MAY OCCUR ON FLAT FOUNDATION SLOPE	HIGH PIEZOMETRIC PRESSURES IN FOUNDATIONS. IN SOME CASES, SAND BOILS MAY BE PRESENT PRIOR TO COMPLETE FAILURE.
PLANAR FAILURE		WEAK PLANE IN DUMP MATERIAL APPROXIMATELY PARALLEL TO DUMP FACE, DUE TO POOR MATERIAL, SNOW LENS OR RAPID LOADING.	MAY INVOLVE LARGE AMOUNT OF MATERIAL WITH LARGE RUNOUT DISTANCE.	SLUMPING OF DUMP CREST, BULGING OF TOE OR FACE, CRACKS ON PLATFORM WELL BEHIND CREST.

- cracks giving indications of the degree of subsidence may grow in size in proportion to the value of movement detected by instrumentation, which should be installed in areas where cracks develop. All cracks should be filled in to form a smooth road access to the dump crest and to control infiltration of surface water. Operators of haul trucks and bulldozers should be on the lookout for cracks and slumping on the dump crest and should notify the foreman immediately if such features develop. Potential instability for mine dumps may be indicated by a slight concave curvature as the observer looks from the top of the berm down the fall-line to the toe. This curvature may occur as a result of toe bulging or oversteepening of the crest; and

- oversteepening of the slope directly beneath the crest is often the result of rapid accumulation of fine material near the crest. This buildup of material will often be steeper than the angle of repose and will very likely lead to sliver failures on the face and possibly involving the crest.

8.2.2 Dump Slope

Visual clues of instability on the dump slope are bulges formed during settlement of material. Bulging can develop at the crest, centre or toe of the dump slope. Crest and centre bulging is caused by oversteepening of the slope beyond its usual angle of repose and may be due to poor segregation of dump material, excessive loading rate, or the presence of zones of saturated material. If a bulge is observed, this may be an indication of potential instability. This may not be serious as continued end-dumping will gradually bring the slope to its angle of repose. However, if oversteepening continues, a large area of the crest can be affected and dumping should be discontinued until slope movement subsides.

Toe bulging is an indication of large-scale settlement. Mine dump failures are usually preceded by toe bulges, but not all toe bulges precede failure. If toe bulging is observed, careful examination of the monitoring results should be conducted. If instrument monitoring has not been carried out, it should be considered immediately. If growth of the bulge continues, dumping in the area should be discontinued until the

slope stabilizes. Once movement of the slope subsides as indicated by instrumentation, dumping activity can be resumed with caution.

8.2.3 Dump Foundation

The cause of many large-scale dump failures can be linked to failure of the foundation material. This may be indicated by heaving of the foundation material ahead of the dump toe. This condition should be assessed regularly.

8.2.4 Acoustic Monitoring

An audible indication of impending failure can sometimes be detected at the toe of some dumps composed of coarse material. This "rock noise" in the toe abutments is often apparent prior to upslope failure. For several hours or days prior to failure, the level and frequency of the noise may increase. The noise is probably the result of fracturing of soft material or stick-slip movement along the surfaces of hard rock. Detection of such noise is always justification for relocating dumping activity until equilibrium is re-established.

8.3 Instrumentation

This section presents an overview of mine dump instrumentation and monitoring. A current study funded by Energy, Mines and Resources Canada (CANMET, 1991) will produce a detailed report on this subject. That report is scheduled for completion in the first half of 1991.

8.3.1 Wireline Extensometers

Extensometer is a term applied to any one of several devices which serve to measure the change in distance between two points. Extensometers may be read manually, or linked to recording devices to provide a continuous plot of movement versus time. They may be periodically interrogated by a telemetry system, or they may be equipped with limit switches which will activate warning devices when a pre-set rate of movement is exceeded. When deciding on which type of wireline extensometer to use,

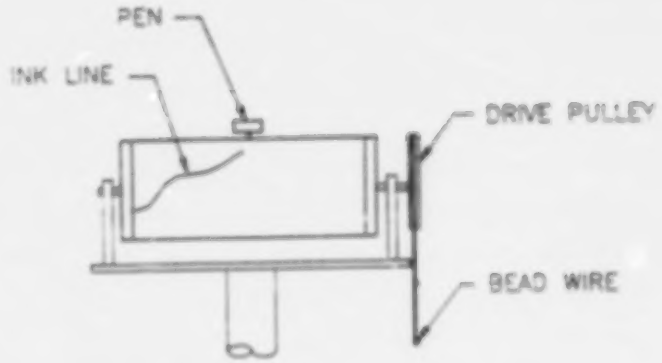
consideration must be given to the component of movement that each will measure. Depending on the type and location of the instrument, different installations may give different indications for the same slope. The movement recorded is the component of displacement parallel to the orientation of the wire between the moving end and the first sheave. The simplest types of extensometer are preferred by most mining operations which monitor mine dumps. They can be easily read and adjusted by the foreman, dump person or other responsible person with basic training. Several configurations of wireline monitors are given in Figure 8 to Figure 11.

8.3.2 Surveying

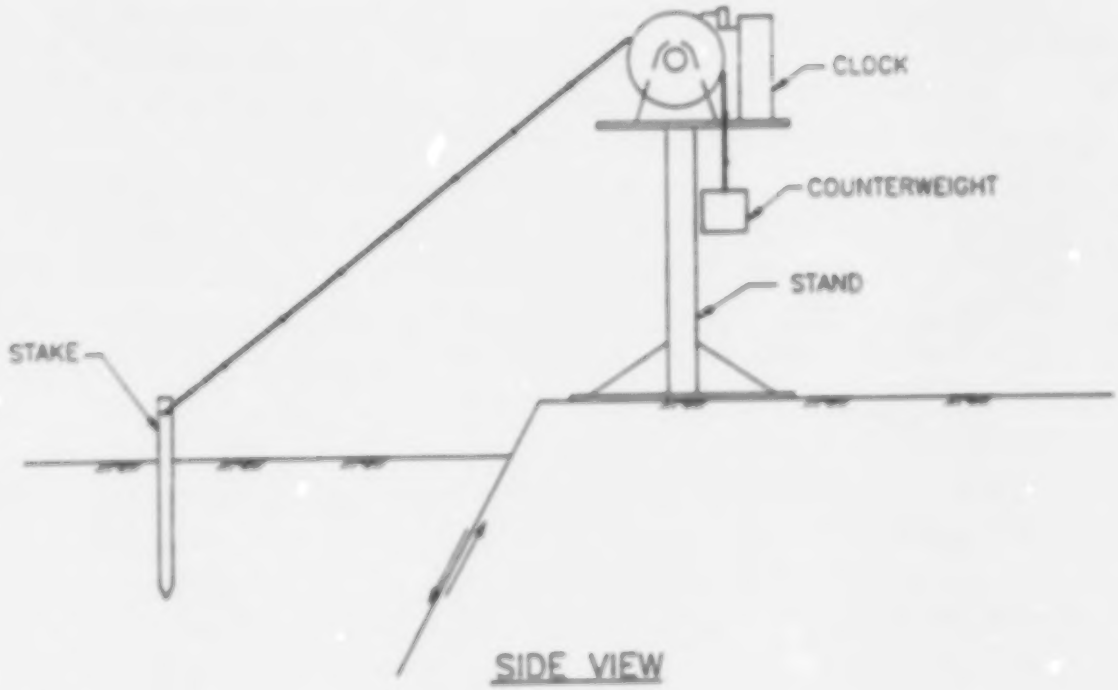
Various surveying techniques including conventional transit and stadia, level, electronic distance measurement (EDM), and photogrammetry have been employed to monitor displacements associated with dump movement. Surveying is used extensively in many mines as an economical and expedient way of gathering vertical settlement and total displacement data. The major disadvantage is that survey measurements usually represent discontinuous data, and frequent measurements are necessary to adequately define short-term trends. In addition, this method of monitoring crest displacement usually requires mobilization of a survey crew, reduction of the data and interpretation of the results, resulting in delays when quick reactions may be required. In cases where crest displacements are progressing at relatively rapid rates, the use of conventional survey methods for obtaining displacement records may be impracticable.

8.3.3 Inclinometers

Inclinometers are commonly used for measuring the horizontal component of movement within an embankment or differential movement across the foundation boundary. Their use is much less frequent than that of extensometers because of cost, relative difficulty of installation and short service life due to the dynamic nature of mine dumps. Currently, there are two available types of inclinometer: fixed and movable.



FRONT VIEW

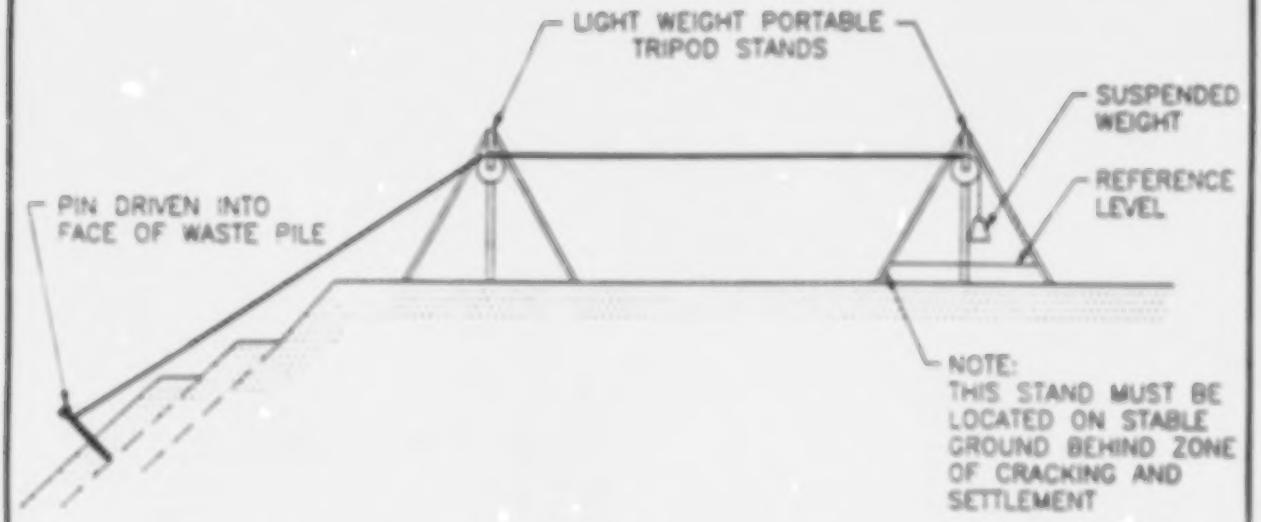


SIDE VIEW

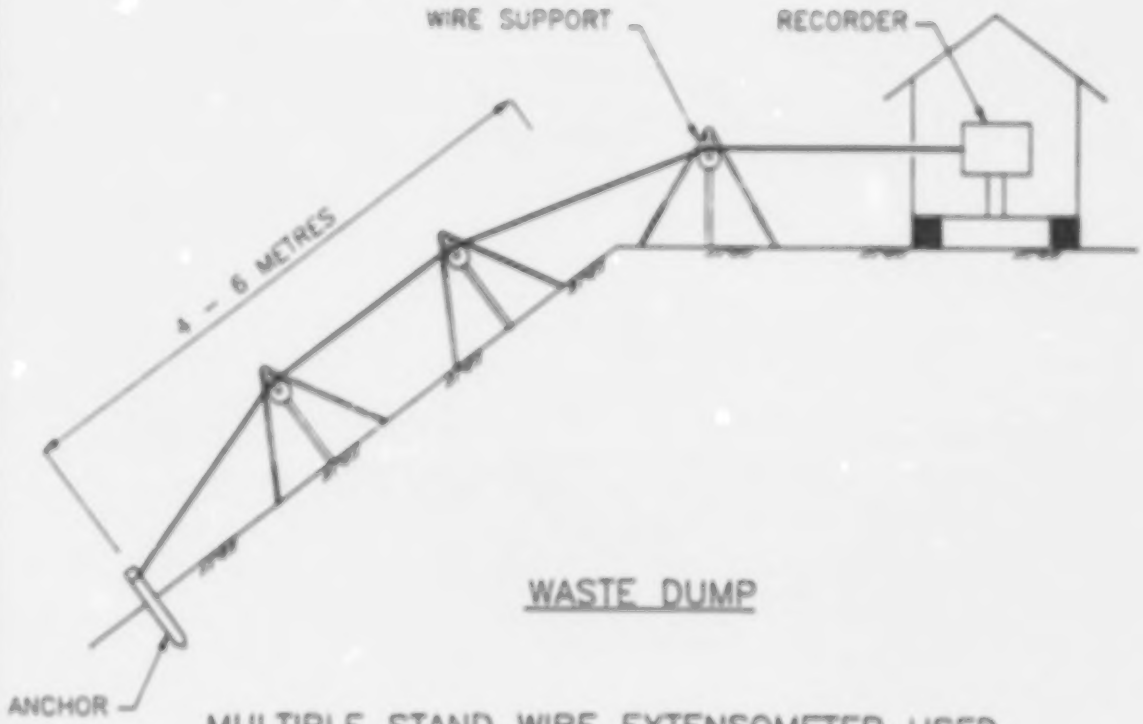
SINGLE STAND WIRE EXTENSOMETER

AFTER McCARTER (1985)

FIGURE 8


LIGHT WEIGHT PORTABLE TRIPOD STANDS
SUSPENDED WEIGHT
REFERENCE LEVEL
PIN DRIVEN INTO FACE OF WASTE PILE
NOTE:
THIS STAND MUST BE LOCATED ON STABLE GROUND BEHIND ZONE OF CRACKING AND SETTLEMENT

TWO STAND WIRE EXTENSOMETER

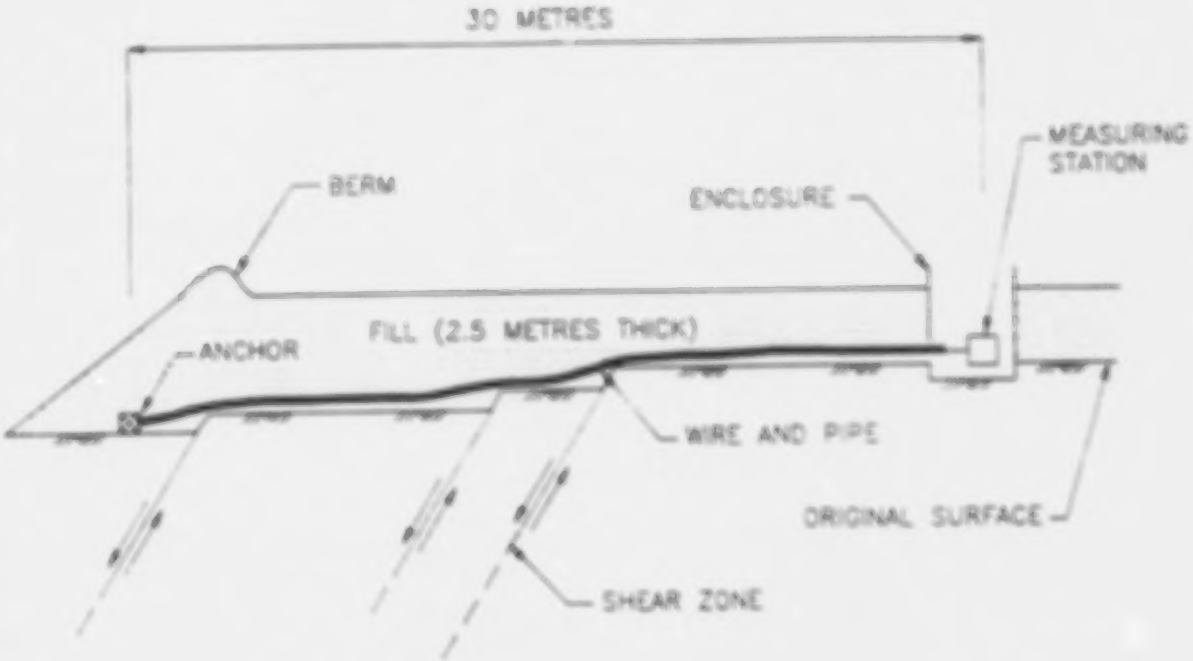


WASTE DUMP

MULTIPLE STAND WIRE EXTENSOMETER USED TO MONITOR MOVEMENT OF THE INCLINED SURFACE OF A DUMP

AFTER McCARTER (1985)

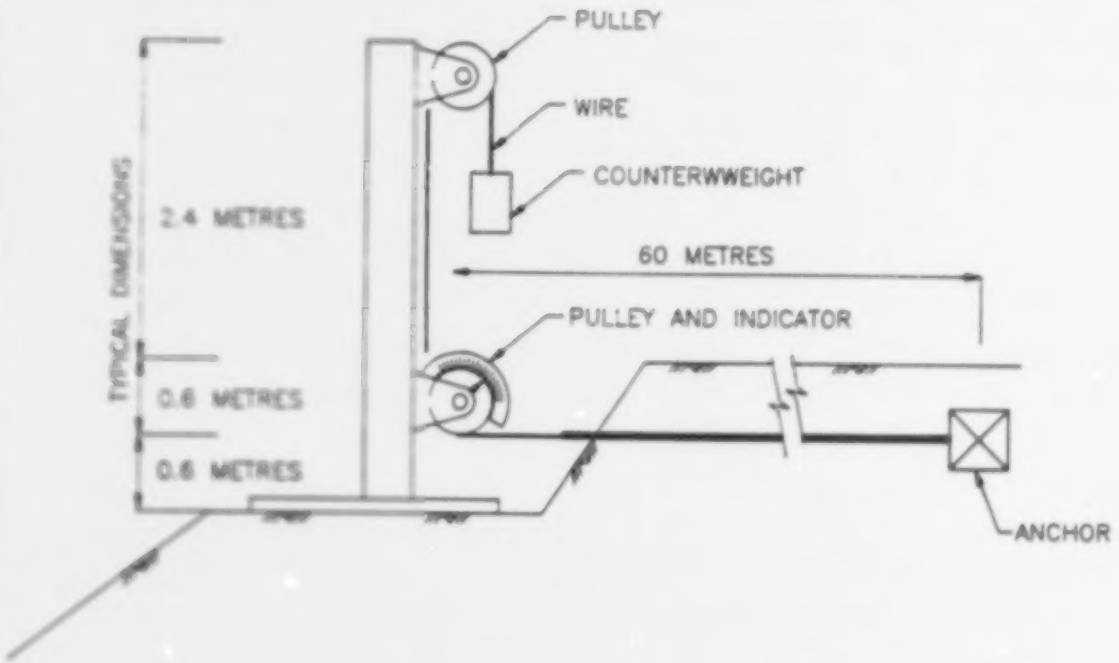
FIGURE 9



BURIED WIRE EXTENSOMETER WITH MEASURING ELEMENT POSITIONED ON STATIONARY END

AFTER McCARTER (1985)

FIGURE 10



BURIED WIRE EXTENSOMETER WITH MEASURING ELEMENT POSITIONED ON ACTIVE END

AFTER McCARTER (1985)

FIGURE 11

8.3.4 Piezometers

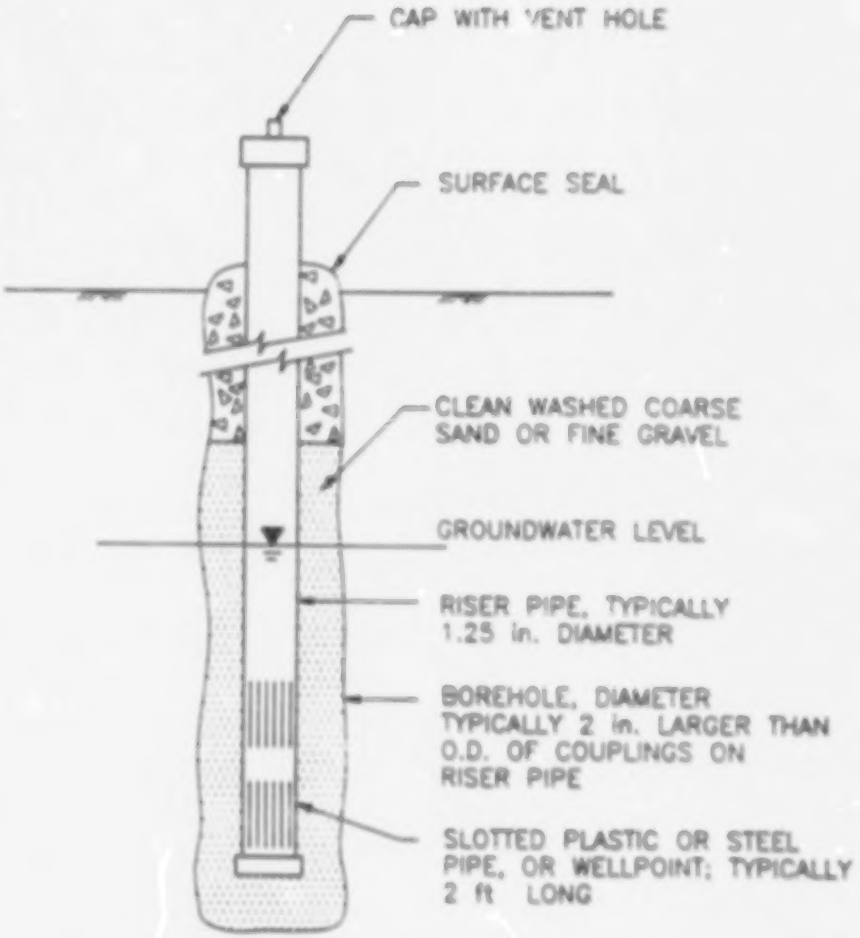
One of the most critical factors affecting the stability of mine dumps is excess pore water pressure within the dump and foundation materials. Piezometers serve to measure pore pressure by admitting water and excluding soil particles and provide a means of measuring the pressure acting through the liquid phase. Various types of piezometer are in use including observation wells, electrical, pneumatic and vibrating wire piezometers. These are illustrated in Figures 12 to 15.

8.4 Data Assessment

Data assessment is a task which should be assigned to competent people with appropriate geotechnical experience. They should be familiar with the technical aspects of the mine dump design, planning of the monitoring program, the project construction procedure, and details of instrument installation, data collection, processing and presentation. They should have computational and analytical skills and should be capable of exercising engineering judgement.

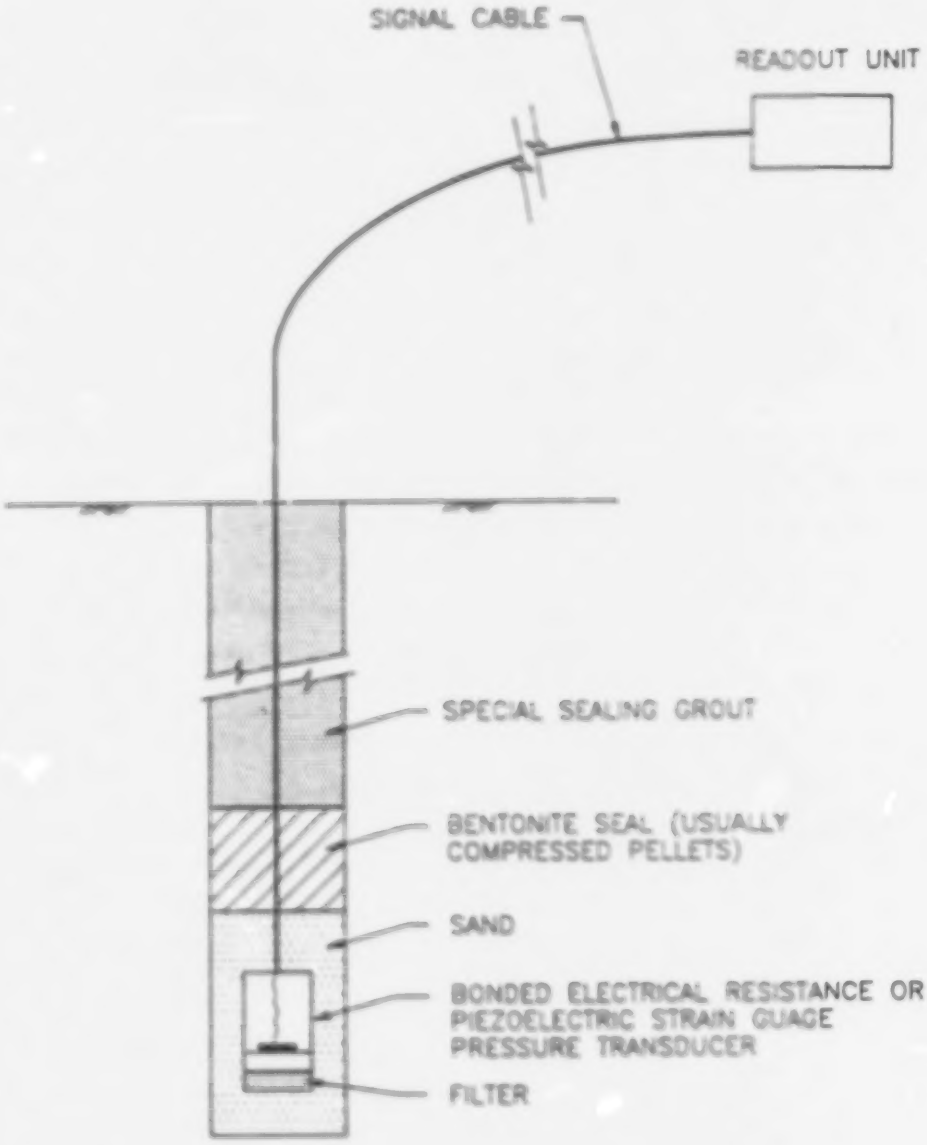
The first aim of data processing and presentation of instrumentation data is to provide a rapid assessment of the data in order to detect changes that require immediate action. The second aim is to summarize and present the data in order to show trends and to compare observed with predicted behaviour so that any necessary action can be initiated.

Data assessment is dependent on factors specific to each instrument and project. The interpretation of instrumentation data should not be delayed until a large quantity of data has been collected and processed because the tasks of collecting, processing and assessment should influence each other. Also, timely response to changes indicated by monitoring results is required. Monitoring data should be thoroughly reviewed by the engineer to determine validity. Details recorded on drill log sheets during installation are particularly helpful when evaluating questionable data since difficulties may have been encountered during installation, resulting in abnormal data.


CAP WITH VENT HOLE
SURFACE SEAL
CLEAN WASHED COARSE SAND OR FINE GRAVEL
GROUNDWATER LEVEL
RISER PIPE, TYPICALLY 1.25 in. DIAMETER
BOREHOLE, DIAMETER TYPICALLY 2 in. LARGER THAN O.D. OF COUPLINGS ON RISER PIPE
SLOTTED PLASTIC OR STEEL PIPE, OR WELLPOINT; TYPICALLY 2 ft LONG

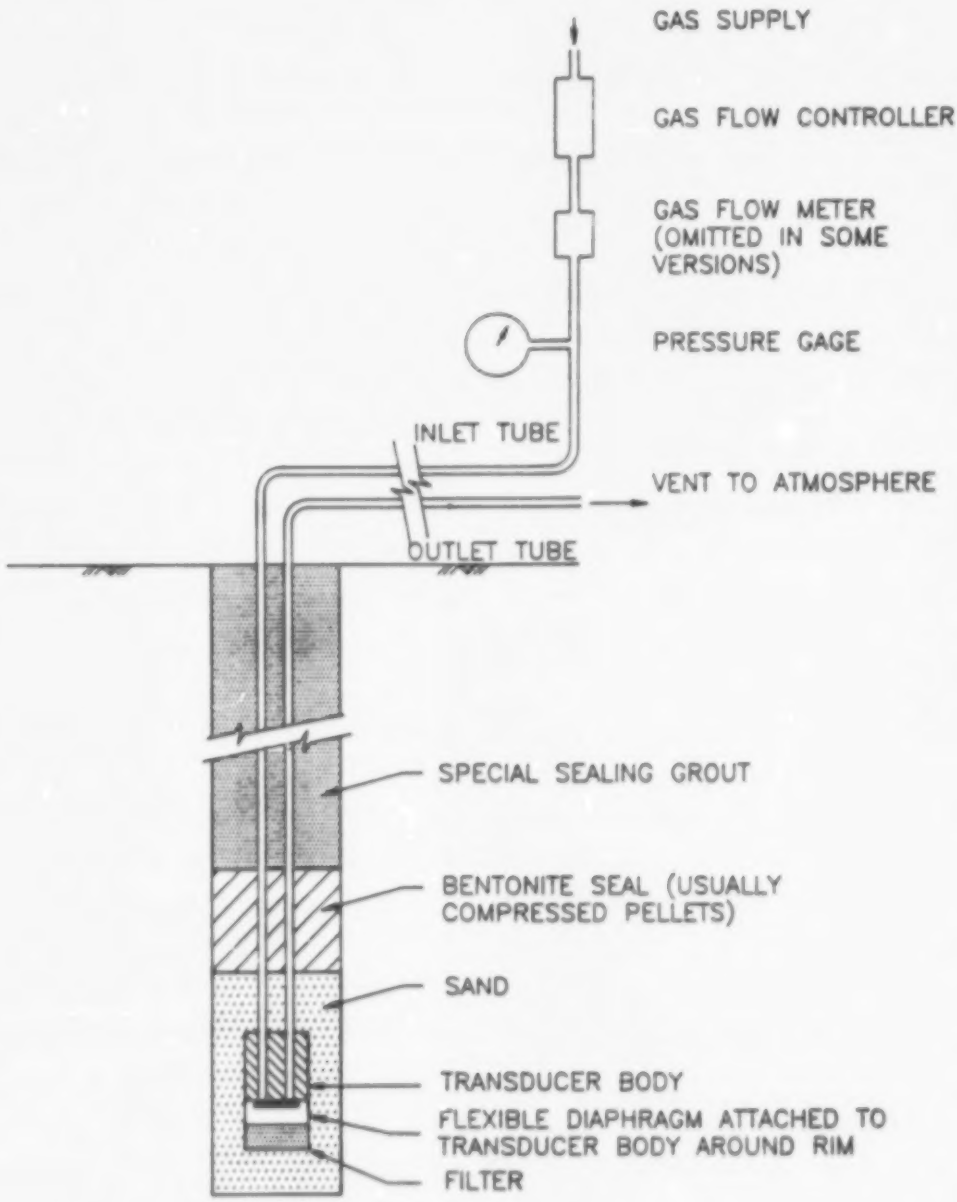
OBSERVATION WELL

FIGURE 12



BONDED ELECTRICAL RESISTANCE STRAIN GUAGE PIEZOMETER INSTALLED IN A BOREHOLE

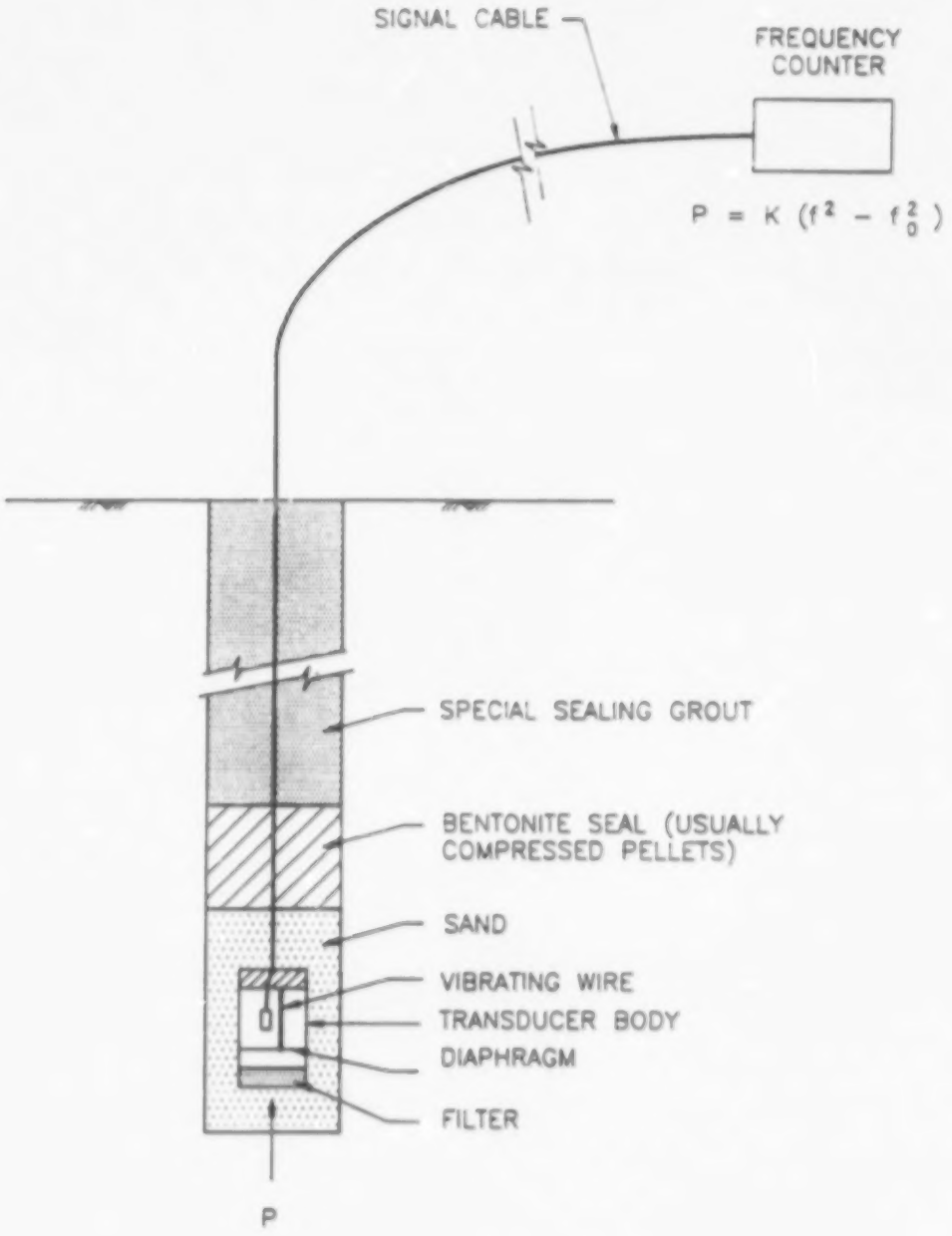
FIGURE 13



NOTE: A THIRD TUBE IS NEEDED TO ALLOW FLUSHING OF THE TIP IF THE PIEZOMETER IS TO BE INSTALLED IN PARTIALLY SATURATED SOILS OR IF NEGATIVE PORE PRESSURES ARE TO BE MEASURED.

PNEUMATIC PIEZOMETER INSTALLED IN A BOREHOLE. (NORMALLY CLOSED TRANSDUCER, WITH TWO TUBES, READ AS GAS IS FLOWING.)

FIGURE 14



VIBRATING WIRE PIEZOMETER
INSTALLED IN A BOREHOLE

FIGURE 15

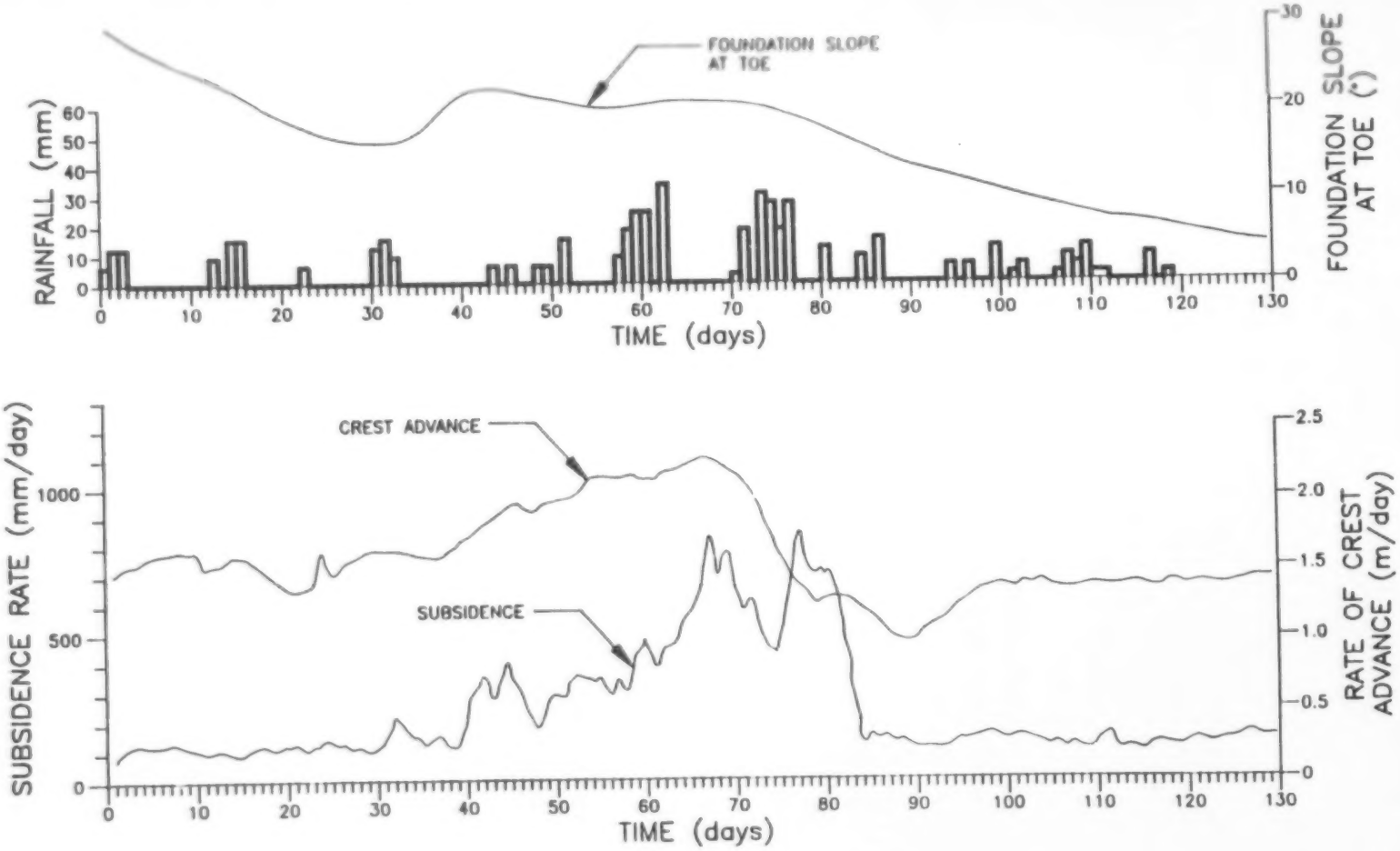
Assessment and reassessment is an ongoing process. Initial assessments should be tentative, dependent on collection of further data. Interpretation may change as a clearer understanding of real behaviour is developed. Assessment of the performance of an individual instrument often requires a study of data over a significant period.

Various types of plots are used in assessing data. They include routine plots of data versus time, plots to assess with predictions, plots for comparing observed and predicted behaviour, plots for comparison of measurements and observations, and plots to examine cause-and-effect relationships. Selection of plots must be made on a case-by-case basis with the purpose of the instrumentation program clearly in mind. An example of data plots is given in Figure 16. From these graphs, relationships between rates of crest advance, precipitation, foundation slope and crest movement can be readily seen.

8.5 Reporting Requirements

General reporting requirements concerning all aspects of mine dump operation are discussed in Section 9, Monitoring, Inspection, Reporting and Record Keeping Requirements and summarized in Table 8. Monitoring information will form a part of most mine dump reports, including the shift report, quarterly and annual in-house reports, the periodic detailed log and inspection reports by independent reviewers.

For dumps requiring instrumentation, monitoring data should be reviewed daily by the designated engineer (see Table 8, Section 9) or other qualified person. This review will often involve updating plots and calculating rates of movement.



PLOTS OF SUBSIDENCE, CREST ADVANCE, RAINFALL AND FOUNDATION SLOPE AGAINST TIME

FIGURE 16

MAY 22, 1991

Monitoring information to be included with the periodic detailed inspection (see Figure 17, Section 9.5, Mine Dump Inspection) should include:

- updated summary plots;
- a brief commentary highlighting attention to all significant changes that have occurred in the measured parameters since the previous periodic detailed inspection report, together with probable causes; and
- recommended action.

The quarterly or annual in-house report is prepared to document key aspects of the monitoring program and to support any remedial actions. It should contain the following information:

- summary of report;
- introduction, including a brief description of the project and the reason for using geotechnical instrumentation;
- any design and construction information that is relevant to the monitoring program;
- summary of the monitoring program planning phase;
- description of instruments and readout units;
- plans and sections sufficient to show instrument numbers and locations;
- representative photographs;
- appropriate surface and subsurface stratigraphic and geotechnical data;
- instrument calibration and maintenance procedures;
- procedures for data collection, processing presentation and interpretation;

- observed behaviour, including summary plots and factors that influence measured data;
- analysis of observed behaviour, including comparison between measurements and predictions, a discussion of significant changes, and probable causes and comparisons with published information; and
- conclusions, discussion and recommendations including a statement of any remedial actions taken.

The in-house report should also have an assessment of the monitoring program, which should include instrument performance, calibration and installation techniques, adequacy of data collection, processing, presentation and interpretation procedures, and recommendations for specifying future monitoring programs.

8.6 Actions Required

Instrumentation Readings

The basic purpose of mine dump monitoring is to provide warning of impending failure. The monitoring system used should be capable of detecting the earliest indication of possible failure.

An example of movement criteria for mine dumps is given in Table 7. Site-specific movement criteria or guidelines should be developed for correlation with instrumentation readings. These guidelines will assist in deciding when precautionary measures should be taken if movement is detected. Each case will have a different set of criteria which will be developed based on experience with the dump materials, including material type, shear strength, pore water pressure, and dump height.

Table 7 - Typical Mine Dump Movement Criteria

STATUS	DAILY RATE OF MOVEMENT	INTERVAL BETWEEN READINGS	ACTION REQUIRED
1	Shift start	-	Review last shift's monitoring report to assess dump behaviour.
2	0-170 mm	4 hours	Normal.
3	170-250 mm	2 hours	Caution advised.
4	250-330 mm	1 hour	Caution advised, visual observation important.
5	330-425 mm	1 hour	Extreme caution, frequent visual observation, foreman to instruct truck drivers to dump short and dozer operator to push material off dump. If possible, try to use another dump location.
6	425-500 mm	1 hour	Short dump only or alternate. Alternative dump location.
7	>500 mm	1 hour	Stop dumping in this area and close the dump. Use alternative dump locations.

This table is not intended as a guideline for movement rates. It is for illustration only, to indicate the typical actions required for different possible movement rates.

NOTES:

1. If only one reading of 500 mm/day is recorded, dumping is suspended. This suspension continues until 12 hours of consecutive readings below the critical rate of 500 mm/day are observed.

2. If consecutive readings of 500 mm/day are recorded, dumping is suspended. This suspension continues until 24 hours of consecutive readings below the critical rate of 500 mm/day are observed.

3. Inoperative dumps must be monitored 24 hours before dumping is initiated. Intervals between readings will be four hours.

8.7 Requirements for Closure and Reopening

Based on movement criteria discussed above, temporary suspension of dumping operations due to excessive deformation is not uncommon. Adherence to the following well-defined guidelines to ensure safety during and following such suspensions is imperative.

8.7.1 Access Restrictions

Closed dumps must be well marked to ensure compliance with dumping and access restrictions. Restricted areas should include dump platforms and any area downstream of the dump which could be affected by debris should a failure occur. Access to dumps undergoing short-term closure can be effectively restricted with prominent signs and fluorescent survey flagging across all entrances to the dump platform. Longer-term restrictions should be imposed by building a berm across the entrance, in addition to appropriate signs.

During closure, dump access should be restricted to essential personnel for monitoring or inspection purposes. Heavy equipment should be kept off the dump.

8.7.2 Reopening Dumps After Closure

As required by the Code, no dump can be reopened after being inactive for four hours or more without inspection by a qualified person appointed by the manager. However, following closure for reasons of instability, more specific criteria are called for. Based on movement rate guidelines discussed above, it is recommended that a dump be monitored on a four-hour or shorter interval for at least 24 hours prior to reopening. During the entire 24-hour period, movement rates must fall within the guidelines developed, and accepted as safe, for the particular dump in question. The decision to reopen a dump closed for reasons of instability or excessive movement must be endorsed by the mine superintendent.

9. MONITORING, INSPECTION, REPORTING AND RECORD KEEPING REQUIREMENTS

9.1 Summary

MINE DUMP CLASSIFICATION

- The mine dump classification system described in the Design Guidelines is adopted.

RECORD KEEPING

- Records should be kept of movement rates, crest advance rate, material quality, weather, blasting, seismic events, original topography.

MONITORING

- Monitoring requirements should be based on dump classification system.

INSPECTION

- Inspection requirements should be based on dump classification system.
- Detailed inspection form to be used.

REPORTING

- Reporting requirements should be based on dump classification system.
- Various reporting formats are described.

9.2 Mine Dump Classification

Monitoring and inspection requirements for mine dumps should be based on a dump classification system. This system must ultimately provide a means of describing the dump in terms of overall risk or consequence of instability or other failure to perform as designed. A Dump Stability Rating Scheme has been proposed (MEMPR, 1991) by which a numerical score can be calculated based on the major considerations. The rating system table is given in Appendix I for reference. In order to promote a uniform approach encompassing dump design and operation, it is recommended that the same rating system be adopted for use. Monitoring, inspection and reporting requirements based on the Dump Stability Rating Scheme (DSR) are presented in Table 8. Four

TABLE 8 MONITORING, INSPECTION AND REPORTING REQUIREMENTS

DUMP STAB. CLASS	DUMP STAB. RATING	REQUIREMENTS				
		INSTRUMENT MONITORING	SHIFT REPORT	INSPECTION		REPORTING
				DESCRIPTION	FREQUENCY	
I	< 300	Visual inspection only unless unexpected movements detected. Piezometers where applicable.	Yes	Shift foreman to inspect. • Periodic detailed inspection by the engineer**.	4 hours Annual	Shift log reports. Annual in-house report.
II	300-600	Instrumentation required if movements other than consolidation settlement noted. Piezometers where applicable.	Yes	Shift foreman to inspect. Inspection and interpretation of instrumentation data by the engineer**, if instrumented. • Periodic detailed inspection by the engineer**.	4 hours Daily Quarterly	Shift log reports. Quarterly inspection. Annual in-house report.
III	600-1200	Instrumentation for movement monitoring required as specified by design consultant. Piezometers where applicable.	Yes	Shift foreman to inspect. Inspection and interpretation of instrumentation data by the engineer**. • Periodic detailed inspection by the engineer**. Inspection by independent reviewer	4 hours Daily Monthly Annual	Shift log reports. Quarterly in-house report. Annual report by independent reviewer.
IV	> 1200	Detailed instrumentation program to be specified by design consultant. Piezometers where applicable. Piezometers probably required in foundations if any fine grained soils present.	Yes	Shift foreman to inspect. Inspection and interpretation of instrumentation data by the engineer**. • Periodic detailed inspection by the engineer**. Inspection by independent reviewer.	4 hours Daily Monthly Annual (minimum)	Shift log reports. Quarterly in-house report Annual report by independent reviewer, or more frequently as required by the District Inspector.

*Periodic detailed inspection refers to inspection form described in Section 9.5.
Shift log report required by the Code. Visual monitoring is required for all mine dumps.
**The engineer is defined as a permanent staff member, a professional engineer or other competent person with appropriate geotechnical experience who is responsible for understanding and implementing all technical aspects of waste dump design and operation.

categories of dump are defined according to the score from the rating scheme. The recommended monitoring and reporting requirements for each category are presented.

9.3 Record Keeping

In order to develop empirical criteria by which to predict instability, it is important that detailed records be kept. From these records the effects on stability of each of the various factors involved can be assessed. A suggested list of pertinent data which should be considered is given below:

- Movement Rates:
  Section 8, Dump Monitoring, discusses movement monitoring in detail. Accurate records of all resulting data should be kept on file.

- Rate of Crest Advance:
  As discussed in Section 7.8, Loading Rates, crest advance rates may have significant effects on dump stability. Records of crest advance rates should be kept for correlation with movement rates and other data. It may then be possible to develop relationships between this data and possible instability.

- Material Quality:
  As discussed in Section 7.3, Material Quality Control, material quality should be monitored. It may be necessary to control dumping of poor quality material or restrict it to certain dump areas.

- Weather Conditions:
  A historical record of precipitation (snow as well as rain) and temperature should be maintained.

- Blasting:
  Blasting records from the open pit operations should be maintained. Where relevant, vibration monitoring to correlate with blasts may be required. Blasting may affect dumps through vibration of dumps or breakage of material to be placed in dumps (see Section 7.3.1, Material Quality Degradation).

- Seismic Events:
  Seismic events should be recorded.

- Original Topography.

These records should be maintained and reported, regardless of the Dump Stability Rating (see Section 9.2, Mine Dump Classification), at the frequencies suggested in Table 8.

All data collected pertaining to mine dumps should be reviewed regularly. If instrumented movement monitoring is indicated, movement data should be plotted and reviewed by the responsible site engineer daily. This will allow for necessary changes to be determined and passed on to mine operations personnel for immediate action.

9.4 Monitoring Requirements

Based on the classification scheme discussed in Section 9.2, Mine Dump Classification, a monitoring program should be defined for each dump and modified as necessary. Due to the unique nature of each mine dump, individual assessments of instrument types, numbers and the frequency of recordings must be made.

Under this scheme, all active Class III or IV dumps require instrument monitoring. Class I and II dumps require instrument monitoring if movements other than normal consolidation settlements are detected. If a dump designated Class I exhibits unexpected deformations or is thought to be otherwise unstable, it should be elevated to Class II.

This scheme is intended as an initial indication of the type and frequency of monitoring required. Detailed monitoring programs for Class III and IV dumps or Class II dumps requiring monitoring must be developed by a specialist geotechnical engineer.

9.5 Mine Dump Inspection

Detailed inspections of mine dumps should be carried out periodically in order to ensure that any changes or irregularities regarding performance, appearance or construction methods are noted. A standardized inspection form has been developed for this purpose (Figure 17). A discussion of the resulting inspection criteria is given below (see also Table 8) and an example of the completed form is provided for illustration. A blank form for reproduction is included in Appendix I.

The first section of the inspection form contains the necessary data to identify the dump and its location. Information required here is the mine name and dump name or number, the date of inspection, the date of the previous inspection, inspector's name and signature.

The second section provides space for a brief written summary of actions taken since and as a result of recommendations of previous inspections.

The third section is a summary of the current inspection and is filled out after the inspection is complete. It provides a summary indicating at a glance whether action is required and in which areas. The inspection checklist (page 2) covers areas of concern which should be reviewed at each inspection. The intent of the form is to provide a quick and comprehensive means of checking the facility and creating a permanent record of inspections. The checklist form is divided into nine major classifications, each with several subheadings. The three columns to the right of each item cover the following response types:

FIGURE 17 MINE DUMP INSPECTION FORM

DUMP DESCRIPTION

MINE: Big Eagle
DUMP NAME OR NUMBER: Cottonwood
DATE OF INSPECTION (YYMMDD): 90 06 15
DATE OF PREVIOUS INSPECTION (YYMMDD): 90 03 17
INSPECTOR'S NAME: John Doe
INSPECTOR'S SIGNATURE: John Doe

SUMMARY OF ACTIONS TAKEN SINCE LAST INSPECTION

- Talked with logging company manager re: debris - still a problem
- Installed piezometers as requested by consultant

INSPECTION SUMMARY

SUBJECT	ACTION REQUIRED			
	NONE	IMMEDIATE REVIEW BY SITE MANAGER	IMMEDIATE REVIEW BY TECHNICAL ADVISOR	EMERGENCY ACTION REQUIRED
GENERAL AREA CONDITIONS	None			
CONSTRUCTION & SITE CONDITIONS	None			
SLOPE & SURFACE CONDITIONS	None			
SEEPAGE	None			
EROSION	None			
STREAM DIVERSIONS		✓		
FLOW THROUGH DUMPS	N/A			
INSTRUMENTATION			✓	
ADDITIONAL CONSIDERATIONS	None			

FIGURE 17 MINE DUMP INSPECTION FORM

CHECKLIST

	CHANGES FROM PREVIOUS INSPECTIONS	VARIANCE FROM DESIGN	ACTION TAKEN
GENERAL AREA CONDITIONS			
DOWNSTREAM AND DOWNSLOPE DEVELOPMENT	NC OK	NC	
WATERSHED CONDITIONS	NC - B		
STREAM CHARACTERISTICS	NC OK		
CONSTRUCTION AND SITE CONDITIONS			
FOUNDATION PREPARATION	NC OK		
PLACEMENT OF MATERIALS	NC OK		
HAULROADS & ACCESS ROADS	D		
GENERAL SITE APPEARANCE AND MAINTENANCE	NC OK		
OTHER	NC OK		
SLOPE & SURFACE CONDITIONS			
CRACKING ON PLATFORM	NC OK		
CRACKING ON CREST	NC OK		
CRACKING ON SLOPE	NC OK		
OVERSTEEPENING AT CREST	C		
BULGING OF SLOPE	NC OK		
TOE SPREADING	NC OK		
OTHER	NC OK		
SEEPAGE			
FROM DUMP FACE	NC OK		
FROM DRAINS	NC OK		
FROM NATURAL HILLSIDES	I E		
OTHER	NC OK		
EROSION			
ON DUMP FACE	NC OK		
ELSEWHERE	E		NDI
STREAM DIVERSIONS			
CLOGGING	NC - A		NM/NDI
EROSION	E		
RIPRAP OR ARMORING	NC OK		
POINT OF DISCHARGE	NC OK		
FLOW THROUGH DUMPS			
CLOGGING AT INTAKE	NA		
EROSION OF FINES	NA		
POINT OF DISCHARGE	NA		
INSTRUMENTATION			
WIRELINE EXTENSOMETERS	NC OK		
SURVEY MONUMENTS	NC OK		
PIEZOMETERS	F		NTA
OTHERS	NC OK		
ADDITIONAL CONSIDERATIONS			
WATER QUALITY	E		
SOIL COVER	NC OK		
VEGETATION	NC OK		
OTHER	NC OK		

SUGGESTED FORMAT FOR CHECKLIST ENTRIES

CHANGES COLUMN

NA - NOT APPLICABLE
NC - OK - NO NOTICEABLE CHANGE AND CONDITION ACCEPTABLE
NC - A - NO CHANGE BUT SEE NOTE "A"
I - IMPROVED SINCE LAST INSPECTION
NOTE "A", "B", ETC.
SEE SUPPLEMENTAL INFORMATION SHEETS

VARIANCE COLUMN

NA - NOT APPLICABLE
NV - NO APPARENT VARIANCE
NOTE "A", "B", ETC.
SEE SUPPLEMENTAL INFORMATION SHEETS

ACTION TAKEN COLUMN

NONE
NM - NOTIFIED MANAGER
NTA - NOTIFIED TECHNICAL ADVISOR
NDI - NOTIFIED DISTRICT INSPECTOR

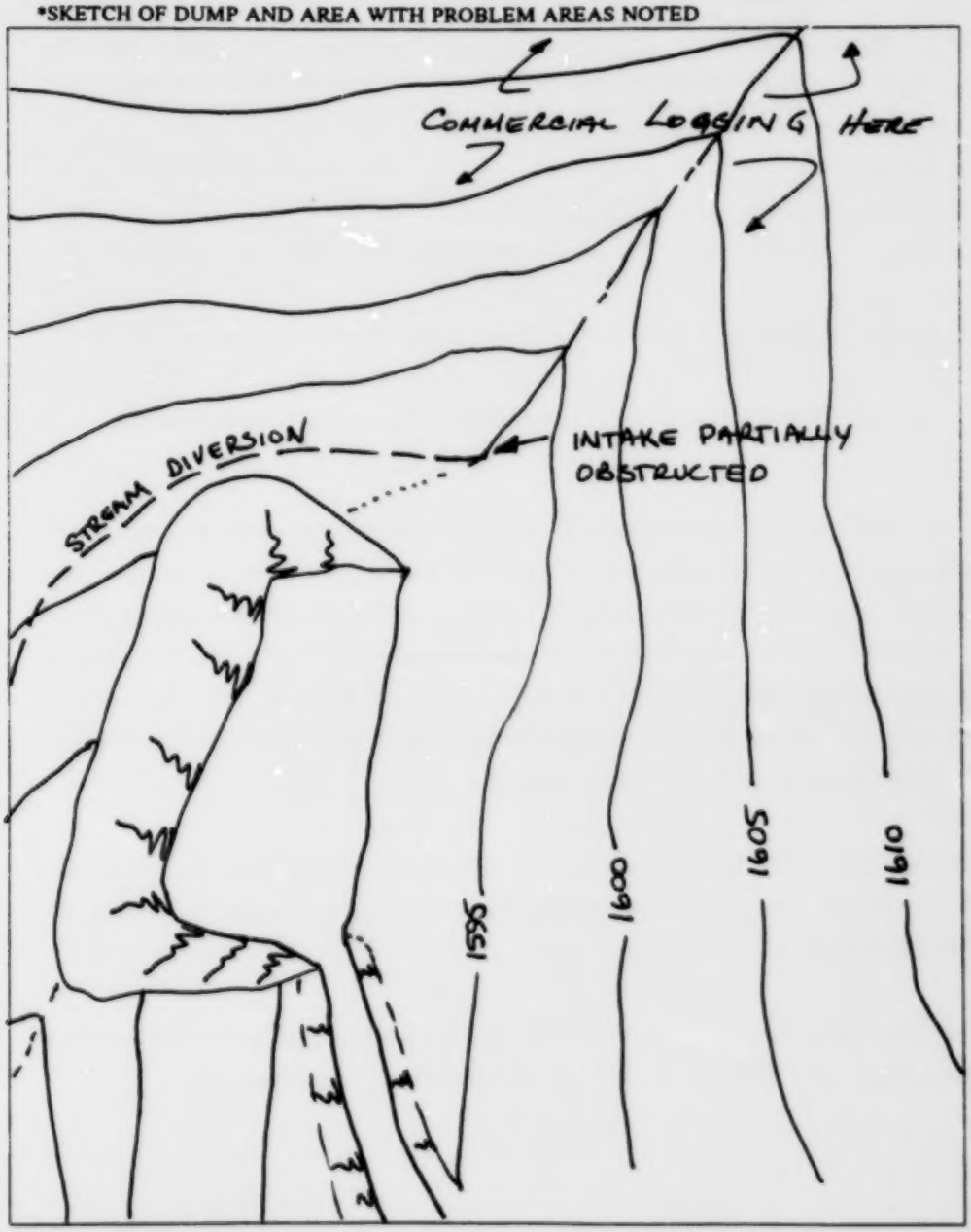
FIGURE 17 MINE DUMP INSPECTION FORM

SUPPLEMENTAL INFORMATION

NOTE	DISCUSSION
A	Stream diversion blocked at upper end due to debris from logging operation - mostly branches, sticks & some mud & sand. Should be cleaned up this summer before winter rains begin. Talked to logging contractor - they acknowledge problem but have not yet addressed it.
B	Logging in watershed upstream of dump - see NOTE A also.
C	Some crest steepening due to high fines in dump. Will be out of Bearpaw mudstone by July so problem should diminish.
D	New haulroad access from 1595 pit exit.
E	Muddy water from logging upstream
F	Three new piezometers installed in toe area to measure pressures in foundation.

FIGURE 17 MINE DUMP INSPECTION FORM

*SKETCH OF DUMP AND AREA WITH PROBLEM AREAS NOTED



*ALTERNATIVELY ATTACH ANNOTATED PLAN

- Column 1 (Changes from Previous Inspections) notes any perceived changes from the previous inspection. To avoid the potential for dangerous situations to be noted, then lost in subsequent inspections because they are entered as "no change" despite the fact that a problem still exists, the changes column must include entries such as:

  NC-OK — This means no change and the situation is appropriate;

  NC-G — This means no change but some abnormality is described in note "G".

- Column 2 notes any changes from the mine dump design specifications.

- Column 3 notes any actions taken by the inspector, usually in the form of notification of advisors.

Most responses will take the form of either the abbreviated responses listed at the bottom of the form or references to notes on the supplemental information form (page 3). Page 3 of the form is the supplemental information sheet and is concerned with written notes or explanations of conditions noted on the checklist. For example, on page 2 of the example form under Stream Diversion, clogging, note "A" has been entered. Note A appears on the supplemental information sheet and describes the debris blocking the stream diversion channel.

Page 4 of the form (Sketch of Dump and Area) is for a sketch or scaled plan of the dump with problem areas noted. The location of the clogged diversion is shown on the example sketch.

This type of detailed inspection is recommended at a frequency dependent on the dump rating (Class I, II, III or IV; see Section 9.2, Mine Dump Classification).

9.6 Reporting

As described in Table 8, the requirements for reporting should be dependent on the dump classification. It is required by the Code that a shift log be kept for all dumps. In addition, it is recommended that an annual in-house summary report be prepared for Class I and Class II dumps. For Class III and IV dumps, it is recommended that quarterly in-house summary reports be prepared and that an independent specialist reviewer report on dump performance and stability annually.

In addition to the above recommendations, further reporting requirements may be imposed at the discretion of the District Inspector.

10. FAILURE REPORT AND BACK ANALYSIS

The consequences of mine dump failures in terms of human life, property and the environment are potentially severe. Detailed reporting, evaluation and relevant back analysis of a failure can contribute to an understanding of failure mechanics and cause and lead to better practice to avoid future occurrences.

10.1 Summary

FAILURE REPORT

- Detailed failure report format is presented and should be completed following failure.
- 'Advice of Geotechnical Incidents or Unusual Occurrences' also to be submitted (Code).

BACK ANALYSIS

- Back analysis useful for understanding failures and predicting or preventing future occurrences.

10.2 Failure Report

The failure report must be a clear, concise and complete record of the failure. The information is often required to promote a better understanding of the cause and mechanics of the failure and to allow back analysis of the failure. A detailed reporting format is suggested here (see Table 9). The reporting form is intended as a checklist with more detailed information to be appended. In addition, it is required to complete the form 'Advice of Geotechnical Incidents or Unusual Occurrences' (see example in Appendix I) for submission to the MEMPR, Engineering and Inspection Branch. For large failures, an independent review should be carried out by a specialist.

It is understood that it may not always be possible or practical to collect all of the data suggested. However, an effort should be made to compile as complete a description of the failure as is reasonably attainable. Similarly, there will commonly be more relevant data than can be included on the one-page summary form. In this case, additional attached documentation should be referenced on the summary.

TABLE 9 MINE DUMP FAILURE REPORT

MINE _____

DUMP _____

DATE (YYMMDD) _____

TIME (24 hr clock) _____

LOCATION

North Latitude _____

West Longitude _____

Elevation of top of dump (masl) _____

Elevation of toe of dump (masl) _____

Elevation of top of failure surface (masl) _____

Elevation of toe of failure surface (masl) _____

FAILURE TYPE AND GEOMETRY

Describe the failure surface in terms of shape and material involved (e.g. dump material, overburden, bedrock). Also include detailed topography before and after failure and strategic sections if possible. _____

VOLUME OF FAILED MATERIAL (m3) _____

RUNOUT DISTANCE (m) (dump toe to debris toe) _____

RUNOUT ANGLE (dump crest to debris toe) _____

SPEED OF FAILURE (m/s) _____

MATERIAL DESCRIPTION

Percentage of each material type making up failed debris such as sandstone, shale, unaltered diorite, etc. For each material type give strength information and gradation if available. Attach additional information where possible. _____

FOUNDATION CONDITIONS

Describe stratigraphy, grain sizes, slope angle, seepage zones. _____

PIEZOMETRIC INFORMATION

Describe piezometric conditions (e.g. saturated or drained dump, high or low piezometric pressures in foundation) and attach supporting data. _____

MONITORING DATA

Movement rates and history with supporting data. _____

WEATHER DATA

Note any significant precipitation events. _____

DUMPING RATES

In terms of metres per day of crest advance. _____

SEISMIC INFORMATION

Note any natural seismicity or large blasts. _____

PREVIOUS FAILURES (Y/N?) attach reports _____

Refer to text for more details. Attach any relevant supplementary information.

10.2.1 Failure Location and Date

Describe the failure in terms of longitude, latitude and elevation range and the date and time of occurrence.

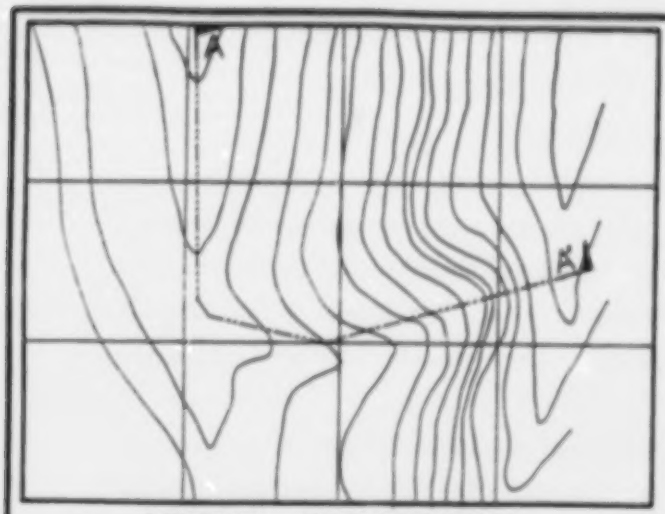
10.2.2 Geometry of Failure

Whenever possible, detailed topography of natural ground as well as pre- and post-failure dump surfaces and debris should be supplied. If detailed topography is not available, crests and toes and as many intermediate slope points as practical should be provided. A profile through the centre of the failure and along the centreline of the runout, including the deposition area, should be prepared. Where several different material types are present in the dump (e.g. sandstone, shale, till), estimates should be made of the percentage of each constituent. When available, strength and durability information for each material should be recorded, such as unconfined compression (UCS) and Los Angeles abrasion (these are ASTM standard tests).

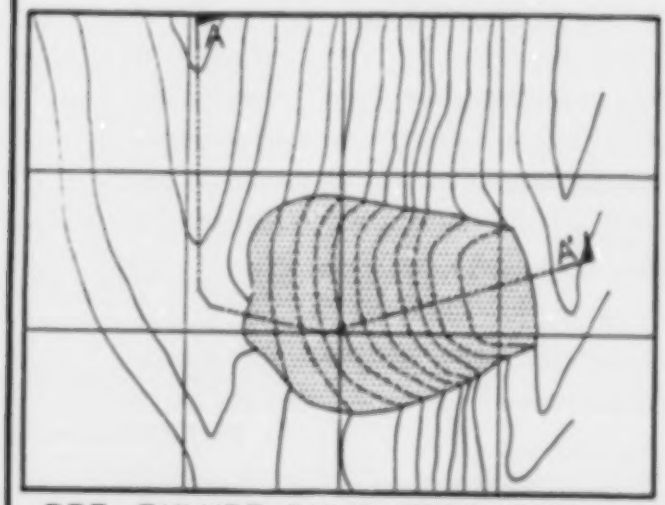
Where the dump foundation is involved in the failure, foundation conditions should be described in as much detail as possible. This should include soil types, stratigraphy, grain-size distributions, density, Atterberg limits (where applicable), piezometric information and strength parameters. Outlines and profiles through deposited debris should also be included. An example of the type of information desired is given in Figure 18.

10.2.3 Volume of Failure

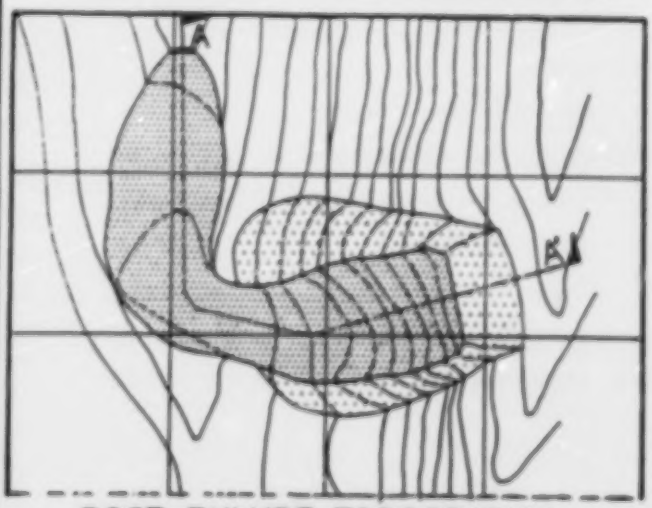
The volume of failed material can be estimated from the topographic or profile information described above. Manual volume calculations are usually based on end areas for a series of representative sections. Computer methods provide quick and possibly more accurate volume calculations using three-dimensional modelling or volumes between digitally modelled surfaces.



ORIGINAL TOPOGRAPHY



PRE-FAILURE DUMP TOPOGRAPHY



POST FAILURE TOPOGRAPHY

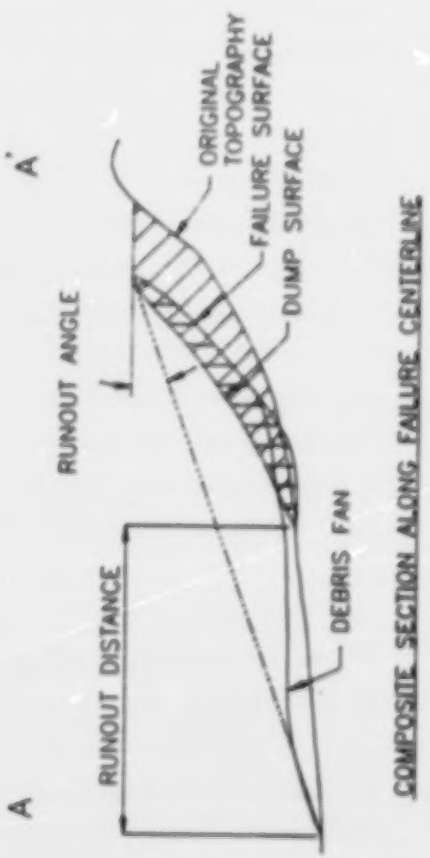


FIGURE 18

10.2.4 Runout

Runout distance has obvious consequences for personnel, equipment and buildings located below the dump. There are also potentially significant environmental concerns. Runout should be described by distance from the original dump toe to the toe of the debris and by the runout angle. Runout angle is measured as the angle below horizontal from pre-failure dump crest to the toe of the debris (see Figure 18). Runout angle should be measured on a vertical section along the centreline of the travel path. This will be a composite section for curved runout paths as shown in Figure 18.

10.2.5 Material Description

A full description of the failed material should be completed. This includes material type and grain-size distribution of the debris and of material on the failure surface. Photographs of the debris and failure surface are very useful in describing conditions. Photographs should be taken at various levels of detail (e.g. entire failure, failure scarp, close up of debris) to fully document the situation. Whenever practical, include something recognizable for scale (e.g. coin, vehicle, person).

A description of the angularity of the failed debris and a comparison with unfailed dump material may be valuable in determining degradation, residual strength and the failure mechanism and nature.

The moisture content of the debris and the material left behind on the failure surface should be estimated.

10.2.6 Piezometric and Seepage Data

Piezometric pressures can play a significant role in the failure mechanics. Any piezometer data available for the dump or foundation materials should be included in the failure report.

Also of interest is any available information on seepage zones or wet ground, either in the failure debris or on the failure surface. Immediate inspection after failure on foot

can usually locate most areas of seepage or wet ground. Infrared imagery has also been used successfully to delineate areas of variable wetness. If infrared photographs are available for various times (e.g. preconstruction, during operation and post-failure), they may be indicative of seepage patterns and piezometric relationships important to failure.

10.2.7 Monitoring Data

Complete monitoring records for the period preceding failure must be included in the report. This would include visual qualitative records as well as quantitative data from instrumentation. Any recent pre-failure photographs should be included.

10.2.8 Weather Data

Rain and snowfall as well as barometric records and temperatures should be documented for the period leading up to the failure.

10.2.9 Dumping Rates

Dumping rates prior to failure (recorded as m/day of crest advance) are essential to the report. If detailed records have not been kept, rates of crest advance can be estimated by comparison of periodic surveys of crest and toe locations.

10.2.10 Seismic Information

Documentation should be provided of any earthquake activity or large blasts which may have had an effect on stability.

10.2.11 General Area

A description of the general area of the failure should not be overlooked. Photographic documentation is useful (various levels of detail) to present the overall scene. Other observed details, such as evidence of air blasts, sand boils or any other diagnostic information, should be included.

10.3 Back Analysis

Back analysis of failures is a useful means of calibrating models of dump performance. Verification and refinement of design assumptions concerning material strength and behaviour are possible. At the time of failure, and only then, do we know the factor of safety with any certainty. The best opportunity to determine the geometry of the failure surface may present itself immediately after the failure as well.

An important question in back analysis of a failure is which of several analysis techniques to use. Before making this choice, some attention should be given to determining the mode of failure as this will influence the analysis method.

A good estimate of the failure surface geometry should be made whenever possible. This will often rule out failure analysis methods which assume a circular or elliptical failure surface, or those that use a search routine to determine the surface with the lowest factor of safety.

In general, one should gather as much pertinent detail as possible regarding the mode and geometry of the failure. With this information in mind, one or more appropriate analysis methods should be chosen. With the overall factor of safety assumed to be 1.0 at the time of failure, parametric or sensitivity analysis is recommended to assess the relative importance and possible values of other important factors (e.g. piezometric pressures, shear strengths).

The development of an understanding of past failures will help to avoid, or at least predict, future failures.

10.4 Action Following Failure

10.4.1 Immediate Action

Each mine must be prepared to react appropriately in the event of a mine dump failure. If the dump was not already closed, dumping operation must cease immediately. As

discussed in Section 6.7, Manual for Dump Operation and Emergency Preparedness, an emergency plan must be in place to deal with such occurrences. Responsibilities must be clearly defined in advance to avoid confusion and ensure an appropriate and efficient response to the situation at hand.

10.4.2 Short-Term Action

As soon as is practical following failure, but without compromising the emergency response, the failure should be documented as discussed in Section 10.2, Failure Report. The MEMPR form "Advice of Geotechnical Incidents or Unusual Occurrences" must also be completed and submitted to the District Inspector.

10.4.3 Rehabilitation of Failed Dumps

Dump failures often leave steep head scarps (much steeper than angle of repose), presenting problems for resuming dumping operations. The oversteepened crest inhibits safe access to dump material over the dump face. Several solutions are possible, including blasting to regain an angle of repose slope, scaling using dozers and chains, dumping in other areas to advance a dumping face laterally across the failed area, or dumping short and dozing material over the edge using constant supervision.

Tassie (1988) reported success with blasting to quickly return the crest area to a usable configuration with no scaling required. Due to the unique situation presented by each dump and failure, detailed assessment and sound engineering judgement will be valuable in determining the best solution.

11. MONITORING AND MAINTENANCE OF OLD DUMPS

11.1 *Summary*

- Most dumps' stability improves with time.
- In some cases stability decreases.
- Reclamation plan for closure and abandonment must address long-term stability and monitoring concerns.
- Want to achieve stable, vegetation-covered slopes.
- Slope flattening is required in some cases.
- Surface water flows are important.

11.2 General Considerations

Mines in British Columbia are subject to Code requirements for a "reclamation plan for the closure or abandonment of the mining operation with reference to, and consistent with, Sections 10.5 and 10.6". This plan should be prepared by a qualified professional engineer and will include details regarding the need for ongoing monitoring and maintenance of mine dumps, including specification of monitoring type and frequency. The following discussion is given as background to this requirement.

In general, mine dumps are more subject to instability during construction than after abandonment. As dumps age, settlements occur, resulting in denser material and higher shear strength. Elevated piezometric pressures in fine-grained foundation soils usually resulting from rapid placement of dump materials will dissipate with time. Both of these factors will tend to promote increasing stability of the dump.

However, there are cases where dump stability may decrease with time. Factors leading to loss of stability include the following:

- Dumps that are constructed of degradable material such as slaking shales may be subject to decreasing stability. In this case, reasonable competent rock breaks down to become fine-grained material with very low strength and low to moderate hydraulic conductivity.

- Dump stability may decrease as a result of changes in piezometric conditions within or beneath the dump. Of particular concern are mine dumps whose hydrological design is based on stream diversions or high permeability drainage zones within or beneath the dump. Care should be taken at the design stage to ensure the integrity of diversions (e.g. against overtopping), drains (against plugging by material degradation or foreign material) or other water controlling mechanisms. Those responsible for dump operation and construction must ensure proper adherence to design specifications.

- Internal drainage in dumps may also be affected by migration of fine-grained material to drainage zones causing plugging or blinding of the zone. The resultant decrease in hydraulic conductivity may cause a buildup in piezometric pressures with a resultant decrease in stability.

- Mine dumps with particular environmental concerns may require inspections other than movement monitoring. Dumps designed and built to mitigate acid generation potential or pollution from heavy metals may require ongoing water quality checks to prove their performance.

The above concerns must be considered when determining appropriate post-mining monitoring requirements, and the strategy for closure will be included in the final reclamation report. Another significant concern should be the potential effects of failure. Following inspection and review, many mine dumps may be judged safe, requiring no further observation. Others may require inspection on an annual or semiannual basis and following unusual precipitation or seismic events. In many cases, the need for periodic inspection may diminish as physical and/or chemical stability is proven.

The effects on drainage patterns of long-term subsidence should be considered for abandoned dumps. Differential settlement due to variable vertical thickness of the dump may disrupt planned drainage and result in ponding on the dump surface. Cracks resulting from settlements may provide openings which promote seepage into the dump. The reclamation plan for closure and abandonment should consider these possibilities and make provision for checking and remedial works, if required. A survey

at the time of abandonment and a subsequent survey to assess settlement, combined with visual inspection for significant cracks, are recommended.

11.3 Preparation for Reclamation

Reclamation of mine dumps can be summarized as the establishment of stable, vegetation-covered slopes and flat surfaces. The Committee on Disposal of Excess Spoil (1981) defined the primary benefits for reclamation through establishment of vegetative cover as:

- enhancement of infiltration or percolation of surface water;
- stabilization against wind and water erosion;
- abatement of air and water pollution;
- conservation and amelioration of soil;
- promotion of a beneficial post-mining land use; and
- enhancement of appearance.

Revegetation of slopes often requires slope flattening to ensure overall and creep stability of the surface which, in turn, promotes development of vegetation. Conversely, the development of vegetative cover serves to stabilize the slope against erosion. There are also cases and environments where revegetation may be considered unnecessary. In steep mountainous terrain as is common in British Columbia, talus slopes form a part of the natural landscape. Mine dump slopes of a similar nature may be considered appropriate. In these situations, stability may be the primary or sole concern.

11.4 Slope Flattening

Flattening of slopes to an overall slope angle of 26° is generally accepted as a suitable criterion for revegetation. However, steeper slopes have been successfully revegetated at some British Columbia mines. At 26° or flatter, water erosion will be limited and

infiltration is enhanced. Soil creep, which can inhibit development of good vegetative cover, is also minimized. Most mine dumps are developed by end-dumping, resulting in intermediate slope angles equal to the angle of repose, or generally about 37°. Bulldozing material down from the crest is the method most often used to flatten these slopes. Practical aspects of slope flattening are discussed by Golder (1986) and Berdusco and Love (1985). The amount of material required to be bulldozed is proportional to the square of the slope height. This results in a significant effort required to flatten high slopes built at the angle of repose.

To minimize material rehandling, it is desirable to develop dumps in lifts with intermediate berms or with wraparounds. The economics of this will depend on the mining geometry and sequencing, but should be considered whenever possible in the planning stage.

11.5 Surface Water Diversion

The primary intent of surface water diversion is to minimize flows over steep sections of mine dumps to avoid excessive erosion. Surface diversions are generally considered in the design stage and should address needs of the construction phase as well as the long-term requirements of abandonment.

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Following is a list of the more useful references compiled as a result of this investigation. Many of them are referenced directly in the text while others are included here as further sources of information.

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ADVICE OF GEOTECHNICAL INCIDENT OR UNUSUAL OCCURRENCE

FIGURE 17 MINE DUMP INSPECTION FORM

DUMP DESCRIPTION

MINE _____

DUMP NAME OR NUMBER _____

DATE OF INSPECTION (YYMMDD) _____

DATE OF PREVIOUS INSPECTION (YYMMDD) _____

INSPECTOR'S NAME _____

INSPECTOR'S SIGNATURE _____

SUMMARY OF ACTIONS TAKEN SINCE LAST INSPECTION

_____

_____

_____

_____

_____

_____

_____

_____

_____

_____

INSPECTION SUMMARY

SUBJECT	ACTION REQUIRED			
	NONE	IMMEDIATE REVIEW BY SITE MANAGER	IMMEDIATE REVIEW BY TECHNICAL ADVISOR	EMERGENCY ACTION REQUIRED
GENERAL AREA CONDITIONS				
CONSTRUCTION & SITE CONDITIONS				
SLOPE & SURFACE CONDITIONS				
SEEPAGE				
EROSION				
STREAM DIVERSIONS				
FLOW THROUGH DUMPS				
INSTRUMENTATION				
ADDITIONAL CONSIDERATIONS				

FIGURE 17 MINE DUMP INSPECTION FORM

CHECKLIST

	CHANGES FROM PREVIOUS INSPECTIONS	VARIANCE FROM DESIGN	ACTION TAKEN
GENERAL AREA CONDITIONS			
DOWNSTREAM AND DOWNSLOPE DEVELOPMENT			
WATERSHED CONDITIONS			
STREAM CHARACTERISTICS			
CONSTRUCTION AND SITE CONDITIONS			
FOUNDATION PREPARATION			
PLACEMENT OF MATERIALS			
HAULROADS & ACCESS ROADS			
GENERAL SITE APPEARANCE AND MAINTENANCE			
OTHER			
SLOPE & SURFACE CONDITIONS			
CRACKING ON PLATFORM			
CRACKING ON CREST			
CRACKING ON SLOPE			
OVERSTEEPENING AT CREST			
BULGING OF SLOPE			
TOE SPREADING			
OTHER			
SEEPAGE			
FROM DUMP FACE			
FROM DRAINS			
FROM NATURAL HOLLOWS			
OTHER			
EROSION			
ON DUMP FACE			
ELSEWHERE			
STREAM DIVERSIONS			
CLOGGING			
EROSION			
RIPRAP OR ARMORING			
POINT OF DISCHARGE			
FLOW THROUGH DUMPS			
CLOGGING AT INTAKE			
EROSION OF FINES			
POINT OF DISCHARGE			
INSTRUMENTATION			
WIRELINE EXTENSOMETERS			
SURVEY MONUMENTS			
PIEZOMETERS			
OTHERS			
ADDITIONAL CONSIDERATIONS			
WATER QUALITY			
SOIL COVER			
VEGETATION			
OTHER			

SUGGESTED FORMAT FOR CHECKLIST ENTRIES

CHANGES COLUMN

NA - NOT APPLICABLE
NC - OB. - NO NOTICEABLE CHANGE AND CONDITION ACCEPTABLE
NC - A. - NO CHANGE BUT SEE NOTE 'A'
I - IMPROVED SINCE LAST INSPECTION
NOTE 'A', 'B', ETC.
SEE SUPPLEMENTAL INFORMATION SHEETS

VARIANCE COLUMN

NA - NOT APPLICABLE
NV - NO APPARENT VARIANCE
NOTE 'A', 'B', ETC.
SEE SUPPLEMENTAL INFORMATION SHEETS

ACTION TAKEN COLUMN

NONE
NM - NOTIFIED MANAGER
NTA - NOTIFIED TECHNICAL ADVISOR
NDI - NOTIFIED DISTRICT INSPECTOR

FIGURE 17 MINE DUMP INSPECTION FORM

SUPPLEMENTAL INFORMATION

NOTE	DISCUSSION

FIGURE 17 MINE DUMP INSPECTION FORM

*SKETCH OF DUMP AND AREA WITH PROBLEM AREAS NOTED

*ALTERNATIVELY ATTACH ANNOTATED PLAN

ADVICE OF GEOTECHNICAL INCIDENT OR UNUSUAL OCCURRENCE

PROVINCE OF BRITISH COLUMBIA
Ministry of Energy, Mines and Petroleum Resources

ENGINEERING AND INSPECTION BRANCH

ADVICE OF GEOTECHNICAL INCIDENT OR UNUSUAL OCCURRENCE

PART A: This part of the form is to be completed by mine management to advise the Inspector of Mines of a geotechnical event or unusual occurrence.

GENERAL INFORMATION

Name of Mine: _____ Number and Type of Mine: _____

Mining Company: _____ Location: _____

Manager: _____ Appropriate Contact: _____

Phone: _____ Fax _____ Phone: _____

Part of Mine Involved/Affected: _____

Date of Event: _____ Probable Time: _____

Summary of Incident: _____

_____

_____

DETAILS OF EVENT

Conditions at Site Preceding Event (weather, shutdown, etc.): _____

_____

Volume or Mass Involved: _____

Detailed Description of Incident (sketch on back): _____

_____

_____

Damage or Consequences: _____

_____

Actions Ordered or Taken by Mine: _____

_____

_____

_____

ADVICE OF GEOTECHNICAL INCIDENT OR UNUSUAL OCCURRENCE

PART B: This part of the form is to be comp :ed by the Inspector of Mines if the geotechnical event or occurrence which is documented is considered by him to be a dangerous occurrence, warranting follow-up.

EQUIRY

Engineering Report Requested (yes or no) _____

Report from Mine (including plans and section) attached? _____ coming? _____

Investigation Required by Branch Geotechnical Engineer? _____

Notes: _____

_____

_____

Inspection District: _____ Inspector (name): _____

Date: _____ Signature: _____

Initials and Date Seen: _____

FOLLOW-UP

_____

_____

_____

_____

_____

_____

_____

_____

MINE DUMP STABILITY RATING SCHEME
AND
STABILITY CLASSES

(MEMPR, 1991)

TABLE 5.1
DUMP STABILITY RATING SCHEME

KEY FACTORS AFFECTING STABILITY	RANGE OF CONDITIONS OR DESCRIPTION		POINT RATING
DUMP CONFIGURATION			
DUMP HEIGHT		< 50m	0
		50m - 100m	50
		100m - 200m	100
		> 200m	200
DUMP VOLUME	Small	< 1 million BCM's	0
	Medium	1 - 50 million BCM's	50
	Large	> 50 million BCM's	100
DUMP SLOPE	Flat	< 28°	0
	Moderate	28° - 35°	50
	Steep	> 35°	100
FOUNDATION SLOPE	Flat	< 10°	0
	Moderate	10° - 25°	50
	Steep	25° - 32°	100
	Extreme	> 32°	200
DEGREE OF CONFINEMENT	Confined	-Concave slope in plan or section -Valley or Cross-Valley fill, toe buttressed against opposite valley wall -Incised gullies which can be used to limit foundation slope during development	0
	Moderately Confined	-Natural benches or terraces on slope -Even slopes, limited natural topographic diversity -Heaped, Sidehill or broad Valley or Cross-Valley fills	50
	Unconfined	-Convex slope in plan or section -Sidehill or Ridge Crest fill with no toe confinement -No gullies or benches to assist development	100
FOUNDATION TYPE	Competent	-Foundation materials as strong or stronger than dump materials -Not subject to adverse pore pressures -No adverse geologic structure	0
	Intermediate	-Intermediate between competent and weak -Soils gain strength with consolidation -Adverse pore pressures dissipate if loading rate controlled	100
	Weak	-Limited bearing capacity, soft soils -Subject to adverse pore pressure generation upon loading -Adverse groundwater conditions, springs or seeps -Strength sensitive to shear strain, potentially liquefiable	200
DUMP MATERIAL QUALITY	High	-Strong, durable -Less than about 10% fines	0
	Moderate	-Moderately strong, variable durability -10 to 25% fines	100
	Poor	-Predominantly weak rocks of low durability -Greater than about 25% fines, overburden	200

Continued

TABLE 5.1 (Continued)
DUMP STABILITY RATING SCHEME

KEY FACTORS AFFECTING STABILITY	RANGE OF CONDITIONS OR DESCRIPTION		POINT RATING
METHOD OF CONSTRUCTION	Favourable	-Thin lifts (<25m thick), wide platforms -Dumping along contours -Ascending construction -Wrap-arounds or terraces	0
	Mixed	-Moderately thick lifts (25m - 50m) -Mixed construction methods	100
	Unfavourable	-Thick lifts (> 50m), narrow platform (sliver fill) -Dumping down the fall line of the slope -Descending construction	200
PIEZOMETRIC AND CLIMATIC CONDITIONS	Favourable	-Low piezometric pressures, no seepage in foundation -Development of phreatic surface within dump unlikely -Limited precipitation -Minimal infiltration into dump -No snow or ice layers in dump or foundation	0
	Intermediate	-Moderate piezometric pressures, some seeps in foundation -Limited development of phreatic surface in dump possible -Moderate precipitation -High infiltration into dump -Discontinuous snow or ice lenses or layers in dump	100
	Unfavourable	-High piezometric pressures, springs in foundation -High precipitation -Significant potential for development of phreatic surface or perched water tables in dump -Continuous layers or lenses of snow or ice in dump or foundation	200
DUMPING RATE	Slow	-< 25 BCM's per lineal metre of crest per day -Crest advancement rate < 0.1m per day	0
	Moderate	-25 - 200 BCM's per lineal metre of crest per day -Crest advancement rate 0.1m - 1.0m per day	100
	High	-> 200 BCM's per lineal metre of crest per day -Crest advancement > 1.0m per day	200
SEISMICITY	Low	Seismic Risk Zones 0 and 1	0
	Moderate	Seismic Risk Zones 2 and 3	50
	High	Seismic Risk Zones 4 or higher	100

MAXIMUM POSSIBLE DUMP STABILITY RATING: **1800**

TABLE 5.2
DUMP STABILITY CLASSES AND RECOMMENDED LEVEL OF EFFORT

DUMP STABILITY CLASS	FAILURE HAZARD	RECOMMENDED LEVEL OF EFFORT FOR INVESTIGATION, DESIGN AND CONSTRUCTION	RANGE OF DUMP RATING (DSR)
I	Negligible	-Basic site reconnaissance, baseline documentation -Minimal lab testing -Routine check of stability, possibly using charts -Minimal restrictions on construction -Visual monitoring only	< 300
II	Low	-Thorough site investigation -Test pits, sampling may be required -Limited lab index testing -Stability may or may not influence design -Basic stability analysis required -Limited restrictions on construction -Routine visual and instrument monitoring	300-600
III	Moderate	-Detailed, phased site investigation -Test pits required, drilling or other subsurface investigations may be required -Undisturbed samples may be required -Detailed lab testing, including index properties, shear strength and durability likely required -Stability influences and may control design -Detailed stability analysis, possibly including parametric studies, required -Stage II detailed design report may be required for approval/permitting -Moderate restrictions on construction (eg. limiting loading rate, lift thickness, material quality, etc.) -Detailed instrument monitoring to confirm design, document behaviour and establish loading limits	600-1200
IV	High	-Detailed, phased site investigation -Test pits, and possibly trenches, required -Drilling, and possible other subsurface investigations probably required -Undisturbed sampling probably required -Detailed lab testing, including index properties, shear strength and durability testing probably required -Stability considerations paramount. -Detailed stability analyses, probably including parametric studies and full evaluation of alternatives probably required -Stage II detailed design report probably required for approval/permitting -Severe restrictions on construction (eg. limiting loading rates, lift thickness, material quality, etc.) -Detailed instrument monitoring to confirm design, document behaviour and establish loading limits	> 1200